ENVIRONMENTAL QUARTERLY

OCTOBER • 1959

The Pioneer Space Age Publication of Environmental Simulation, Testing, Engineering and Equipment Manufacturing

INDEPENDENTLY PUBLISHED

Volume 5 • Number 4

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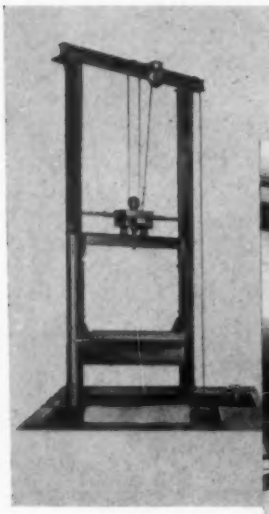

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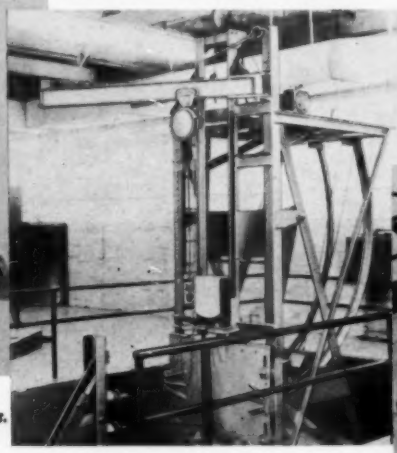

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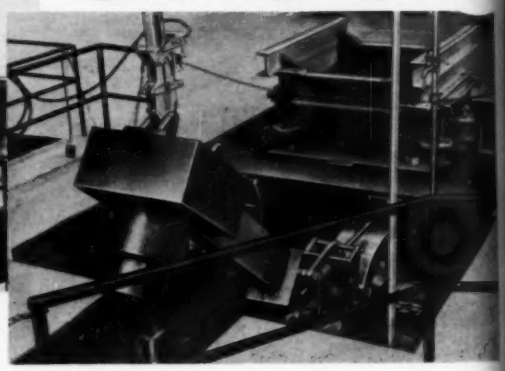
Applicable to MIL-S-901B
MIL-T-17113



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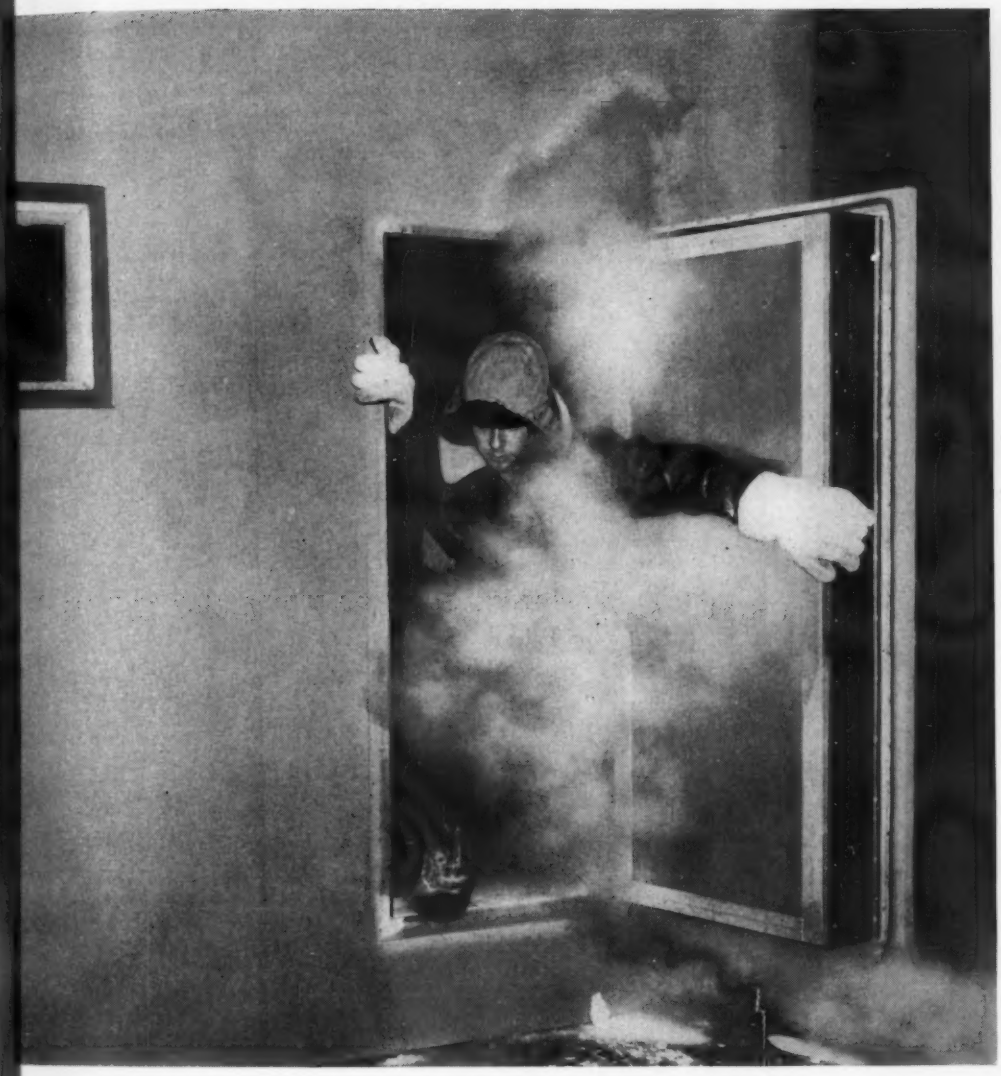

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ENVIRONMENTAL QUARTERLY

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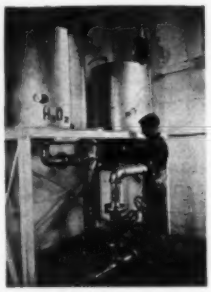
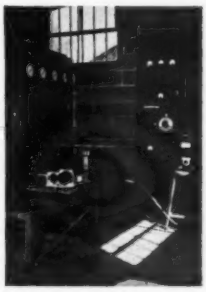
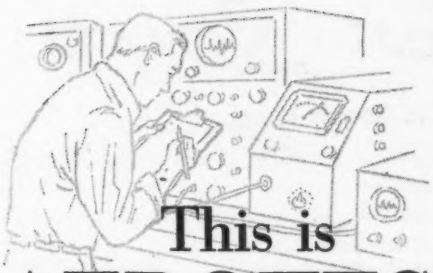
Thorough planning and pre-test study is a vital phase of creative test engineering.



Hydrogen Peroxide flow testing—flow rates to 150 gpm, static pressures to 3,000 psi.



Aircraft and missile vibration testing—to 20 g's and 2,000 cycles per second.



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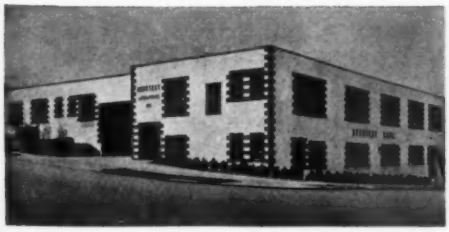

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Post Scripts

• The Old Decade Changeth . . .

At the end of a decade that coincided with the coming of age of the Environment, Environmental Quarterly asked a number of leaders of the field to assess the past and foretell the future. The result is an absorbing group of articles, the first of a continuing series under the general heading of "Path of the Environment."

In this issue you will enjoy "As High as the Sky and Down to Earth," by Harold C. Jones, president of the Institute of Environmental Sciences; "Future Unlimited," by Charles C. E. Harris, president of the Environmental Equipment Institute, and "The Threshold of Knowledge," by E. C. Burkhart, president of Genisco, Incorporated.

The consensus: The past was fruitful; the future is bright, and the Environment, essential tool of the Space Age, will play an even more important role in the sobering, Soaring Sixties and beyond.

• A Seismic Success

The subject of our contents calls for a comment on the Armstrong-Stathopoulos articles on seismic shock and vibration pickup concluded in this issue. They came to our attention through the good offices of an eminent educator who had had a chance to see them in the early preparation stage, and we commend his judgment. We'd like your reaction on this and on the general editorial menu Quarterly has served up this year.

• What's in a Name?

Ask any merchandising man and he'll tell you that the name is very important in popularizing a product. But science is not soap selling, and the short, snappy trademarks that the soap-boxers use to brand their products wouldn't seem to go in a technical field.

The case in point, of course, is "environment" and "environmental." Walk up to a stranger and toss them at him, and he'll be confused at first, possibly thinking of psychological environment or something. But tell him "physical" environment and he'll catch on pretty fast.

Comes now a relatively new environmental testing technique, and a new word to describe it. The technique, of course, is to combine environments. Stellardyne Laboratories' word for combined environments is "Comvironments." We like it and wish it well.

• Your Name's Important

In many ways, your name is extremely important to Environmental Quarterly. First, it belongs on our circulation lists if you work or teach in the environmental field. That covers a lot of territory, but so does Quarterly . . . enough this issue, incidentally, to embrace 5,400 readers—or more, because of the way we get passed around.

But there's no need to relinquish your copy of Quarterly. If you have a colleague or two who doesn't get Quarterly regularly, and who qualifies as a reader by virtue of his interest in the field, all you have to do is to play reader's tag with the postage free reply card bound into this issue.

Your name is also important to Quarterly in its several editorial departments. Has anything happened to you recently? Or to a friend or colleague? Graduated? Gotten married? Had a baby? Promoted? Changed jobs? If you have any news about people in environments, and any pictures of people—especially informal ones—send them along without delay. The address is on our title page. Our readers are our reporters—and you don't have to worry about writing it, although your firm's advertising or public relations people will be glad to help. In any case, we'll handle the prose if you give us the news.

Our Own Sputnik

The Space Age was born on Oct. 4, 19[57] when the Russians loosed their first Sp[utnik]. Hoping to mark the second anniversa[ry] appropriately in this issue of Quarterly, [we] wrote to Moscow earlier in the year see[king] some enlightenment environmental.

At the suggestion of the Soviet embas[sy] in Washington, the letter was addressed [to] the Academy of Sciences asking if one of [its] scientists might not prepare an article [for] us "describing the importance of enviro[n]mental work in your country's rocket pr[o]gram." The letter then explained what e[n]vironmental testing means in the Unite[d] States.

Following is the reply we received fro[m] A. A. Blagonravov, a member of the aca[d]emy, as translated here by a teacher [of] Russian:

"We thank you for your kind letter [in] which you ask us to write an article abo[ut] modeling in the field of rocket technique[s]. You were right in emphasizing the big variet[y] of problems in connection with this kind [of] modeling.

"This variety makes it very difficult for [a] single scientist to write an article."

We haven't given up on that project, [but] until we can report greater success, the[re] is an excellent source of information on Rus[-] sian scientific studies available in this cou[n]try. It is the Office of Technical Services [of] the U. S. Department of Commerce, Wash[-] ington 25, D. C., which publishes Russia[n] technical journals in abstract. One such journal, selling for 70c an issue ($2.50 for four quarterly issues), is called "Refrigera[-] tion Engineering." The OTS will send you a complete list of these journals on request.

Idea Swap Shop

In the July issue, we presented WRM['s] request for more information on transmi[s]sibility reports covering whole missile shak[e] tests and WFV's for data on spark-ga[p] breakdown voltages for altitudes up to 100[,]000 feet.

AHA suggests that WFV might find [a] book by James Dillon Cobine, "Gaseou[s] Conductors" (Dover Publications, Inc., New York), of some help, and adds that he him[-]self is interested in spark-gap breakdow[n] voltages up to 250,000 feet.

"We are in the combined environment [-] test business testing missiles and we, too[,] would like answers to WRM's inquiry for information on transmissibility reports cover[-]ing whole missile shake tests," AHA write[s].

"We also need published information a[s] reports on the outgassing of various type[s] of materials at ultra-low vacuums. Is the[re] such data available? If so, where?"

Can any reader help these readers?

Pats on the Back

If we may, we'd like to quote AHA['s] closing paragraph: "We are very [im]pressed with the attitude of the July, 19[59] issue of Environmental Quarterly and hope that you will continue to expand your serv[-]ices and information."

This is typical of the many letters we have received in recent weeks—many of them with half a dozen or more names of engineers asking to receive "Environmental Quarterly" regularly.

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AROUND THE ENVIRONS...

Air Force Is Victor In Space Role Fight

Amid Russian moon-ing, Congressional grumbling, belt tightening and general reappraisal, the Air Force emerged on the top of the heap in the Defense Department's space program. The Pentagon's Advanced Research Projects Agency, sharply downgraded, returned most of its projects to the armed services whence they had come, and the Army seemed on the way to a secondary space role in the Soaring Sixties.

For example, the reorganization turned the Army's Ballistic Missile Agency at Huntsville, Ala. into a "contractor," and the Pentagon made it clear that even though the Army is developing the 1½-million pound thrust Saturn, the rocket would eventually go to the Air Force.

ARPA, it was explained, would continue to be responsible for advanced research, but the Air Force's is the eventual full responsibility for developing, producing and launching military space vehicles.

Criticism from Capitol Hill

The space-mission shakeup seemed almost in answer to a rather strong suggestion from Capitol Hill that President Eisenhower consider merging the Army and Air Force to cut out duplication in the missile program.

The spectre of a reunited service was raised by Rep. Holifield's Government Operations subcommittee, which declared that merger seemed to be the only way to get rid of "the basic clash" between the two services in the missile field and of the attending duplication and waste.

The committee figured that over the past nine years the military has spent $25 billion on missiles, and that $10 billion of that has gone on only six missiles: Atlas, Titan, Minuteman (all 5,500-mile ICBM's) and Thor, Jupiter and Polaris (1,500-mile intermediate ranges.)

The committee said $2.3 billion has been spent on missiles that never amounted to much, and it found fault with the Pentagon for ordering up both Thor and Jupiter at a cost of $1½ billion to do essentially the same job.

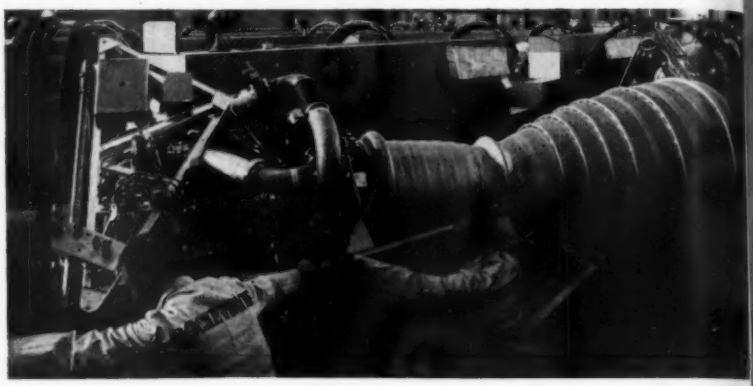
Sudden End of the F-108

In late August, Air Force Secretary Douglas told the "Wall Street Journal" that he might be able to save every major missile and aircraft program despite the economy drive, although it was not to be an easy assignment. Twenty-eight days later, with Premier Khrushchev very much in evidence around the country, North American Aviation's contract for the 2,000 m.p.h. F-108 long-range interceptor was cancelled.

Seeking some consolation in the situation, air officials were reported as saying that part of the $150 million spent on the F-108 would be of value in NAA's related B-70 Valkyrie program, and that the B-70 might well be turned into a supersonic multi-purpose weapon.

The F-108's nosedive left some other projects in an apprehensive state. The Titan ICBM (Martin Co.) was one of the projects defense budgeteers were eyeing axe in hand. It performs about the same job as the Atlas (Convair), which is nearly battle-ready, and is about a year behind Atlas in development. The third big one, the quick-firing, solid-fueled Minuteman (Boeing) may be ready by 1962-3. Some officials were represented as feeling that if something has to go, the middle-link Titan is it.

For a Thor (Destination Unknown)



Swift, light and powerful, Rocketdyne's 150,000-pound thrust IRBM liquid propellant propulsion system is perhaps best known as the first-stage partner of the well-known research team of Thor and Able. Components have been reduced from 46 in early Thor engine configurations to 28 in the model shown coming off the North American Aviation Inc., line in Neosho, Mo. The goal for NAA's designers and testers at Canoga Park, Calif. is a propulsion system with just 1[illegible] components.

Stricter Cost Control Is Word from Air Force

The word from the Air Force is that there will be a closer watch on contractor costs. Soon, it is reported, the service will require a certificate of accuracy from subcontractors with contracts over $100,000 in contracts where there's been no strong competitive bidding for the job.

"You can help us improve our position before Congress if you will cooperate," Lt. Gen. M. E. Bradley Jr., deputy chief of staff, materiel, told contractors at the Air Force Association convention last month.

News Briefs

LOS ANGELES—We have quite a wa[illegible] to go in space technology, says Dr. T[illegible] Keith Glennan, head of the National Aeronautics and Space Administration.

The technical barriers into space are a lot tougher than were realized when NASA was set up a year ago, the civilian space chief said, adding that the Russians aren't such super scientists—they just started in the space exploration field six or seven years before the United States.

* * *

PHILADELPHIA—The biggest chunk of military hardware flung into the sky and recovered—a 12-foot Atlas nose cone—seems to establish the superiority of blowing noses over sniffing.

Built by General Electric's Missile and Space Vehicle Department as was its younger Thor-Able brother (recovered this Spring) the re-entry vehicle was coated with a heat-shield material that vaporized and blew away as it hit the terrific temperatures of the return trip. Thor-Able used the same ablation principle.

Other Thors and Atlases have used the heat sink principle—a shield to absorb heat instead of dissipating it.

* * *

CHICAGO—Looking farther than the moon, the Armour Research Foundation of the Illinois Institute of Technology is trying to find out if anything can live

on Mars. Three tough germs (of pneumonia, food poisoning and tetanus) and two ancient primitive forms of vegetation (mosses and lichens) have been placed in test tubes containing what passes for the Martian atmosphere (98.5 per cent nitrogen, a very small amount of oxygen and carbon dioxide and the rest argon.) The test tubes will be kept at Martian temperatures, which in summer range from 77°F down to 22° below zero.

* * *

SAN ANTONIO—Dr. James A. Van Allen, for whom the earth-girdling radiation belts are named, and Dr. Homer E. Newell Jr., assistant director of NASA, figure that at speeds only one-third that of light a space vehicle will crash into so many hydrogen atoms—nine billion protons and a similar number of electrons per second—as to raise the radiation level to 20 million roentgens an hour. A lethal dose is 1,000, and even if the crew could be shielded, the rocket's exterior probably would deteriorate, they believe.

* * *

CAPE CANAVERAL — Despite the opening of California's Vandenberg Air Force Base as a missile launching site, there's no let up in activity at this originial space base. It's estimated that half a billion dollars have been spent on the Canaveral test center, supporting facilities at Patrick Air Force Base and the 5,000-mile Atlantic range.

Find It on the Moon— Even If You Can't Say It

Should Mare Tranquillitatis and Ptolemaeus become household words, you won't have any trouble locating them with one of General Electric's moon maps. Nearly a yard square and printed in heavenly blue, the map is available from GE's Missile and Space Vehicle Dept., Room 4C, 3198 Chestnut St., Philadelphia 4, Penna.

Well, you should have paid more attention to those Latin courses back in high school.

MISCELLANY: Sales are up but profits are slipping in the electronics industry, according to top industry officials. They attribute it to price competition, marketing problems, research costs and foreign competition . . . *American Bosch Arma Corp.*, Hempstead, N. Y., has received $53,350,000 in contracts for Atlas guidance systems. It will subcontract a major part of the ground support and production test equipment . . . *American Machine and Foundry Co.* has a $42.6 million award to build, install and test the first underground launching system for the Titan ICBM. It will be at Lowry AFB, Denver.

Space Countdown: On Your Mark . . .

Man may shoot out into space from a sort of sprinter's crouch, Air Force studies indicate. The best body position seems to be head and trunk tilted 25 degrees forward and legs sharply bent.

Human volunteers in the Wright Air Development Center's centrifuge in that position stood forward accelerations of 8, 10 and 12 gs, simulating the three-stage kicks of a rocket. They endured 12 g for 5 seconds, 10 g for 23 seconds and 8 g for one minute.

In another g test, this one by the Navy, a volunteer withstood a record 31 gs for 12 seconds. The test used a new technique —a cushion of water between the seated subject and the wall of the centrifuge capsule. A breathing device supplies air. The test was conducted at the Acceleration Laboratory, Johnsville, Pa.

New Underwater Environment

Grumman Aircraft claims a first at its Bethpage, N.Y., plant: A tank that can test hulls and underwater shapes at the once-fantastic speed of 100 knots. A hydraulic transmission precisely controls the speed of rotation of the tank which whirls the water past suspended shapes. The hydrodynamic facility's first use will be on the 80-ton, 80-knot hydrofoil test vehicle being designed for the Maritime Administration under a $250,000 contract.

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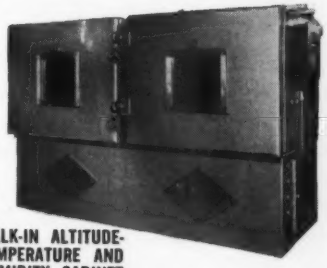

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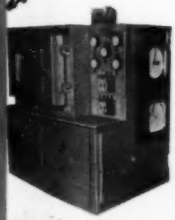

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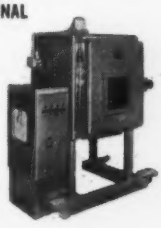

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Path of the Environment:

AS HIGH AS THE SKY — — and down to earth

The head of the Environment's scientific fraternity recalls "an unused corner of a raw materials storage warehouse" and contrasts it with the truly space-age discipline of the turn of the decade. Environmental prediction for the Sixties: Progress on all fronts.

by Harold C. Jones
President
Institute of Environmental Sciences

THE FIRST time that a caveman skinned out his kill and used it as a coat to protect himself from the chill night air, the field of Environmental Sciences was born. Hardly a scientist, the caveman merely did what seemed to him to be the natural thing to do. Thus it was with Environmental Sciences until approximately a decade ago, when it became time to reduce a rambling art, based mostly on superstition with little testing behind it, to a field of science where knowledge was carefully gained, uniformly analyzed and intelligently used.

I remember my first experience with environmental testing about ten years ago. The environmental chamber was located in an unused corner of a raw materials storage warehouse of a large company—one which is now, incidentally, a leader in the environmental field. Our test called for an altitude of 25,000 feet, and to obtain such stratospheric heights required many hours of pumping, many tubes of a sealing compound, and a great deal of ingenuity. Contrast this with our present environmental chambers, capable of rapid rates of climb and tremendous altitudes, where 100,000 feet is commonplace and nobody turns a hair when 500,000 feet is mentioned. It is more expensive, but not exotic anymore.

Unreasonable Chore No More

These brief examples tell volumes, however, of the trend in the field of Environmental Sciences. A decade ago, environmental work was an annoying requirement called for by unreasonable government people. It was a chore that was relegated to anyone who was not busy at the moment. Test equipment was primitive and test methods were sloppy.

Over these last ten years, however, most of the engineering companies producing military equipment have recognized the need for engineers highly trained in the environmental field and for high performance equipment and a great effort has been made to standardize and improve test methods. As a result, many men with higher education, experience and knowledge have devoted their time and effort exclusively to environmental work, and at this point it can honestly be said that environmental work has become a science. It is based no longer on superstition and meager results, but on the analysis of many experiments by highly competent scientists.

With this as background, what does the future hold? Have we reached the point of saturation, or are we just entering an era in which the Environmental Sciences will grow with great rapidity? The answer I feel, is linked closely to our space exploration plans, which are no longer looked upon as the dreams of a few fanatics.

Due to a great deal of publicity most of the public is now quite sure that we are going to colonize the moon, the

Jones

Harold C. Jones has the distinction of being the first man to preside over youthful and growing Institute of Environmental Sciences, formed earlier this year by the merger of the Institute of Environmental Engineers and the Society of Environmental Engineers. He stepped into the presidency after a term as executive vice president of the old IEE, which he helped to organize. A graduate of Illinois Institute of Technology, Jones is a veteran at environmental testing. Before shifting to the University of Maryland, where he teaches in the electrical engineering department, he was with Westinghouse.

planets and so forth. In fact, the public at large is probably more confident of it than some of those who are laying the plans for doing so, since the public does not know the tremendous problems involved.

One of the biggest of these problems will be how to cope with environments which will be found during flight to these foreign bodies and after arriving there. The solution to these problems will fall to those working in the field of Environmental Sciences, and their contribution to our space effort will be great.

But now that we have persons living happily on the moon, there is another aspect of Environmental Science to be looked into, and that one is much closer to home. It involves plain, ordinary civilian, consumer items on this old, tired earth.

Growth In Civilian Fields

All of us have had our troubles with such standard designs as TV sets. In the case of TV sets, these troubles often are traced directly to poor ventilation, which causes excessive temperatures in the cabinet. This is a problem environmental engineers working on military equipment encountered and solved many years ago, and is indicative of the fact that Environmental Sciences must be recognized by consumer goods manufacturers.

Some work in this field is presently being done in the automotive industry, and I feel sure in the next decade the influence of the environmental engineer will be felt in practically all areas of civilian equipment. One reason for this is the fact that, as military equipment manufacturers have found, the services of an environmental engineer more than pays for itself in reduced field maintenance, repairs under warranty and an improved good will.

Scientific Societies

The story of the decade past would be incomplete without mention of the scientific organizations in the field of Environmental Sciences. The growth within the last five years of the Institute of Environmental Engineers and the Society of Environmental Engineers, and the recent merger of the two into the Institute of Environmental Sciences, with a membership which will soon exceed 1,000 engineers, is indicative of the fact that we have evolved from a purely routine testing field into one which is, in the truest sense of the word, a scientific field of endeavor.

DO YOU HAVE A NEW COMPONENT, ASSEMBLY OR END ITEM THAT MUST MEET SOME REQUIREMENT IN ENVIRONMENT?

Acton Laboratories, Inc., offers an environmental testing *service*, meeting both commercial and military specifications, to companies: (1) requiring independent certification of tests, (2) not in a position to justify the purchase of expensive environmental equipment, (3) whose own environmental facilities are in use on other projects.

Our facilities, engineers, and technicians are available to conduct the entire tests; or you may use our facilities and provide your own engineers or technicians to conduct the performance tests.

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ALI

Path of the Environment:

The environmental industry, born of war and nurtured by the space age, has matured rapidly, but even after man conquers space it will have a dominant role in testing th new materials and new products of the morrow.

FUTURE UNLIMITED

by Charles C. E. Harris
President
Environmental Equipment Institute

TO REPEAT a truism, the future of the Environment and of the industry that simulates it, is unlimited. Even after we have conquered space and enter the happy wonderland of Buck Rogers, we shall all turn to environmental testing to prove out the new materials and the new products of the morrow.

Just as World War II, for example, provided the impetus for the use of low temperatures in the steel industry, so have the aviation and space industries helped to boost the entire environmental field to new heights of usefulness in the past two years. The need for environmental testing is not likely to fade. It is here to stay.

The Environment is growing at such a dizzy pace that new problems present themselves as fast as old ones are solved. The environmental manufacturers are proud of the fact that they have been able to lick them—and those still unbeaten await only the investment of more time and effort.

Novelties No More

The experience of the refrigeration end of the industry is typical. Know-how accumulated in many ways over many years made it possible this year to maintain —200°F. by mechanical refrigeration. Although not a novelty today, this extreme was unheard of a couple of years ago.

So, too, with altitude, vibration, gravity and the many other conditions we turn on and off at will. Of course, each success begets new problems because of our insatiable appetite for pushing back the frontiers. There have been quite a few demands recently for low humidities at low temperatures, and it won't be long before reliable refrigeration systems will be replacing chemical dryers to provide dew points of —100°C. and much lower.

So, too, with other combined environments. Consider the transfer of heat in a high altitude chamber. In a perfect vacuum, the transfer can be accomplished only by radiation, which is just about the situation that obtains when you get above 50,000 feet. With convection ruled out, an ingenious use of conduction is called for, engineered to each individual application.

Complicating the Task

Putting anything that does any work into the chamber adds load, making the task that much more difficult. Any sort of load in a stratospheric chamber results in an almost insurmountable obstacle. But notice that I said "almost." I am sure that with time and application, ways will be found to conquer this problem, too.

My faith springs from the history of the environmen industry itself. It was only yesterday that the industry wa a hodge-podge of companies with a multitude of ideas an very little discipline. In short, they reflected the state o the art. Yet in hardly any time at all we have developed flourishing and effective scientific fraternity, a respectabl body of literature and a reliable and competent group o manufacturers from coast to coast.

It was only a half dozen years ago, on Sept. 23, 1953, to b exact, that a group of manufacturers met in New York an organized the Institute of Environmental Manufacturer Later on the name was changed to the Environmenta Equipment Institute.

Objectives Continue to Guide

The objectives of the EEI, as stated in the charter, ar worth noting, because pursuit of these goals has brough about a number of industry successes. One such succe was the formation of an engineering society, now an i dependent, professional organization.

Other successes are on the commercial side. The ob jectives state, for example, that the EEI's purpose is to:

"Establish and maintain standards of construction an performance for environmetal equipment (and) to e tablish and maintain ethical practices in the manufactur sale and servicing of environmental equipment."

Pursuing the first of these, the Institute was successfu in obtaining recognition of the industry as an industr from the Federal Trade Commission. After due deliber tion and public hearings, the FTC promulgated trad practice rules for us in 1957.

'Seal of Approval' Program

Pursuing the second of these goals, we have our co tinuing "seal of approval" program. This is a unique self-policing way of guaranteeing customer satisfaction. I has helped greatly to bring the industry to its presen mature state.

Now, walking confidently into the Sixties, the enviro mental industry is widening its scope and seeking mor formal affiliations on the part of individual companie Through the strength of increased numbers, the industr will be able to serve in the Environment as never before.

Men like Charles C. E. Harris make it difficult to measure the environmental industry in point of time. He's been in it, from the refrigeration end, for a quarter of century, the same span in which he has been in business for himself. His present company, Harris Refrigeration Co., Cambridge, Mass., was formed in 1940. Anyone calling him there must be sure to specify "senior," because "Junior" is following in elder Harris' footsteps. Harris "senior" was elected president of the Environmental Equipment Institute last Spring.

Harris

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Model No. (all units operate from 115 V AC ±10%)	Regulated Output Current	Output Voltage	Regulation Load and Line	Absolute Accuracy	Stability Short Term	Ripple (RMS)	Size Rack Mounted W"H"D"	Net Wgt	Typical Application
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CG-12*	0.5-30 amp dc	0—10	0.05%	2%	0.1%	0.1%	19x14 x22	60#	Rectifier Test
CS-112	0.1μa-10 ma dc	0±100	0.01%	1.0%	0.05%	0.02%	19x 8¾x15	35#	Transistor Test
CS-120	0.1μa-10 ma dc	0—2200	0.1%	1%	0.1%	0.15%	19x 8¾x15	35#	PIV Test
CS-11	1μa-100 ma dc	0—50	0.002%	0.02%	0.001%	0.02%	19x10½x18	40#	Gyro Test
CS-117	0.1μa-150 ma	0±100	0.002%	0.005%	0.001%	0.02%	19x12¾x18	45#	Gyro Test
CS-12	10μa-1 amp dc	0—7	0.01%	0.1%	0.02%	0.05%	19x10½x18	35#	Meter Calibration
CS-1	1-10 amp dc	25—125	1%	2% F.S.	1.0%	2%	19x 8¾x15	60#	Magnetic Field Supply

*CG-12 requires external unregulated power source to supply load power. Other units are completely self contained.

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See North Hills Coil Products in the Radio Electronic MASTER (24th edition), pages 602, 603.

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Path of the Environment:

Ever since he lighted the first fire, or diverted the first stream of water to cultivate his patch, man has been testing and evaluating his environment in order to conquer it. Each bit of information becomes the cornerstone for the next advance, and tremendous progress has been made, but withal we seem to stand only at . . .

The Threshold of Knowledge

by E. C. Burkhart
President
Genisco, Incorporated

STEP BY STEP through thousands of years of trial and error, success and failure, tragedy and comedy, contemplation and realization, man has proceeded to unlock the secrets and basic laws of Nature. Yet we seem only to have arrived at the threshold of knowledge and to be acquainted only with the large, obvious, discernible-to-the-eye sort of natural law, with effect rather than cause. More of Nature seems to be hidden in the tiny atom than in the sum total of natural laws discovered to date.

Practical applications of known laws provide the tools of industry, civilization and further research. In its early stages, development was a process of simple trial and error. Ships to withstand the rigors of the sea were evolved and extended around the designs of those which came back. Bridges and structures were developed in span and capacity from those designs which withstood weather, wind, corrosion and use. Applications of known laws of chemical and molecular structure permitted the assembly of materials not found in their highly purified state on our planet.

The early days of the aeroplane opened up the wholly new science of aerodynamics which related directly to many old arts and sciences of building and structural design. Had the laws of aerodynamics been better understood earlier in time, man would have avoided many tragedies down through the ages.

Suddenly, the Space Age

With the advent of the mechanical age, the pursuit of science, art and technology assumed a new hurried, if not precipitous, attitude. This point in time finds us suddenly, and without adequate preparation, thrust into a totally new space environment which combines with all other environments experienced heretofore.

Try as we may to synthesize this new environment in our laboratories, something is missing. In effect we are back in the cave, almost totally ignorant, playing with fire, once more not quite certain what's going to go boom when the spark is struck and one of Nature's laws, as yet indiscernible, has been violated. But being very aware of Nature's impartial and unforgiving attitude, we are straining to the utmost to anticipate and duplicate the conditions to be encountered, in order that risk be reduced to a minimum.

For we have learned that the hazards can be reduced, even if not totally eliminated, by logical and methodical laboratory testing. Many of the rugged environments to be encountered in space can be synthesized, sometimes combined and in some cases almost duplicated. Meanwhile, researchers are firing more and more missiles skyward. These radio back more and more data on what's there, and we find we need more elaborate and exotic testing equipment to match the marvels of Nature in the laboratory.

The Defiant Environment

One environment which seems to defy all efforts at laboratory duplication is zero G. This condition, a total lack of gravity, has not been produced on earth except for very brief intervals; and unless someone discovers a way of revoking or voiding Newton's law of gravitation it is not likely to be duplicated anywhere except in orbit or in trajectory, essentially in space.

However, zero gravity is not regarded as an intolerable environment to mankind and it is especially kind to machines, equipment and materials. Therefore, except for our

(Continued on Page 14)

Burkhart

E. C. Burkhart is a name that dates back in aviation to 1929. Over the years it has been associated with such names as Fokker, Glenn L. Martin and North American Aviation. Before becoming one of the founders of Genisco, Incorporated, of which he is now president and chairman, Burkhart was supervisor of the research laboratories of Douglas Aircraft Co. He is vice president and a director of the Strategic Industries Association and a member of the Defense Department's Small Business Advisory Committee.

For big walk-ins, small portables, or sizes in between, check with CONRAD Inc.

1000 CU. FT. This temperature-altitude-humidity chambers is the latest of several Conrad chambers installed at one of the nation's largest missile component plants. Temperature range, —100° F. to +350° F.; altitude, 0 to 100,000 ft.; humidity automatically programmed from 20% to 95%. Capable of dissipating 10,000 watts at —100°F.

Other features include rain simulation for testing in accordance with Mil. Spec. 5272 — push-button control for stopping door at any point within a fraction of an inch — push-button alarm system — and inter-com.

8 CU. FT. Adjustable temperature-vibration test chamber. Refrigeration effect is accomplished with liquid CO_2. High temperature limit, +1000°F. Entire unit, including control panel, full mobile.

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The Threshold of Knowledge

(Continued from Page 12)

having to learn its basic rules of behavior, action and reaction, subsistence, food and liquid handling and so forth, we seem to find it no formidable barrier.

Not so the reverse, or high G force conditions. These forces wreak havoc on man and machine and severely restrict the parameters of operation, especially so when combined with vibration, heating, zero pressure (total vacuum) and other equally unfriendly surroundings.

Role of the Centrifuge

A very few years ago a centrifuge was to all intents and purposes either a chemical-medical laboratory tool for separating variable densities in fluids or a cream separator in a dairy doing essentially the same thing. With the advent of jet propelled flight, the simultaneous development of the missile and the dawn of the era of space exploration, centrifugal testing for high G force simulation came into its own.

Parameters have been pushed outward, inward and in all directions—both for testing and calibrating purposes. Components of all descriptions now must be subjected to those forces which will be encountered in actual use, and further, within the bounds of attainability, subjected to simultaneous forces of vibration, stress, strain, shock and the elements of heat extreme, cold and radiation. The little ol' rotating beam whose revolutions were physically counted by sight and whose radius of gyration was measured with a yardstick has become a behemoth of weight and precision to delight the heart of any gadgeteer.

Although there are still many applications for the small crude and small precise centrifuge, the nature of the Space Age is forcing the development and use of larger and larger machines. The largest in existence is located at the Navy's Johnsville, Pa., installation for human tests. This machine, with a 50-foot radius of gyration, takes individuals to the tolerable limits of human endurance under certain conditions of space travel, while the individual is aligned to any and all attitudes which might be encountered in actual travel or re-entry. The purpose, of course, is to determine how to best fit the weak and limited human body to the environment of G force.

Bigger and More Accurate

Larger machines are contemplated—75-foot radius machines have been discussed. In some instances it is desirable to subject full scale rocket motors of 1,000 lb. thrust and above to predetermined G force with the engine operating or to be ignited. The difficult but soluble problem here is to transmit large volumes of highly pressurized fuels through rotary glands in side-by-side configuration. If combined even in small quantities, such fuels produce some alarming reactions. Similarly, large volumes of hot gases must be rapidly bled off the enclosure while retaining reasonable temperatures and aerodynamic stability in the testing pit.

As engines and payloads go up in size and complexity, so too must the means of evaluating components and packages. It is not unreasonable to expect that the very near future will bring requests for centrifuges capable of swinging 25-30 thousand lbs. to acceleration forces of 20-25 G or a total force of 1,500,000 G lbs.

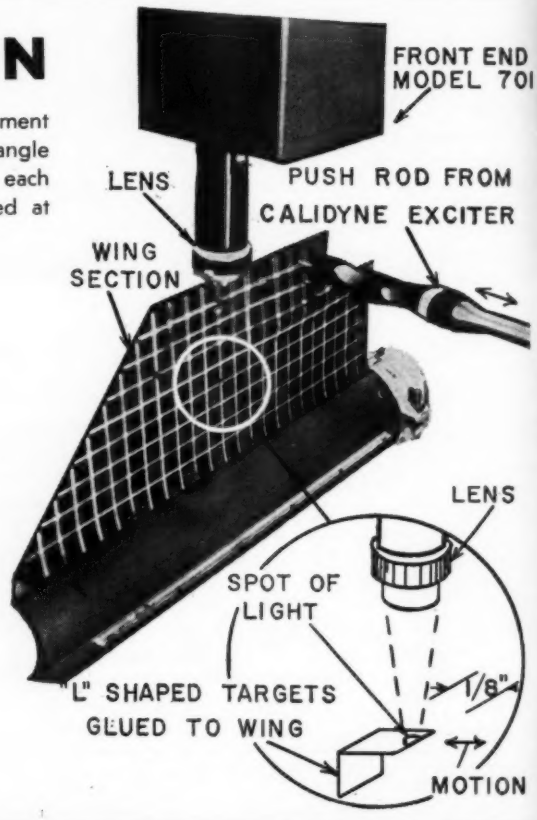
(Continued on Page 46)

WING VIBRATION

New daylight 701 measures amplitude of displacement of selected points on a missile wing. Small right angle targets of .020" aluminum foil ⅛" x ⅛" are glued at each intersection of grid lines. Hard industrial wax gunked at back of target to deaden flutter of target itself.

Spot of light is focused on top edge of target. Wing is driven with horizontal push rod from Calidyne exciter. Vibration measured is perpendicular to wing surface. Instrument may be scanned from point to point without stopping exciter.

Measurements accurate to .001" may be made at a working distance of 56" from lens. Five other interchangeable lenses cover displacement ranges of .050", .100", .500", 1.0", & 2.0" full scale. Best resolution 12 micro inches. Frequency response static to 7 Kc. Output 16 volts full scale, 250 ohms.



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Whether you think of CO_2 and other expendable refrigerant cooling systems as "new" or "old," this type of environmental testing is becoming increasingly important. The following EQ special report—a first report on the subject rather than a definitive word—is based on the experience and thinking of leaders in the field from coast to coast.

The PLUS and MINUS of CO_2

HOW NEW—OR OLD—IS ENVIRONMENTAL TESTING WITH CO_2? To many environmental engineers it is old hat. "The environmental test labs on the West Coast have used it for many years," according to Stuart Giles, chief engineer of Bemco, Inc. "We have chambers in operation for as long as eight years using direct expansion liquid CO_2 or dry ice. We find it is very practical."

J. C. Stuart, of Boeing-Seattle's equipment laboratory, reports:

"Dry ice has been used for many years by Boeing in conjunction with environmental testing. In general its use has been confined to relatively small and short range tests where flexibility and smaller installation costs outweight the cost of operation. Currently liquid CO_2 is being used to reduce compressed air temperature to a desired test inlet condition."

Some users have more recently discovered the merits—and demerits—of CO_2, and some are still experimenting with it.

Associated Testing Laboratories, Inc., a younger East coast firm which, like Bemco and many others, is in both mechanical and CO_2 refrigeration, began fabricating carbon dioxide test units three years ago. "Our testing division," says Bernard Novack, ATL vice president, "uses about 35 liquid CO_2 test chambers, making us possibly the largest user of liquid CO_2 within the environmental testing field."

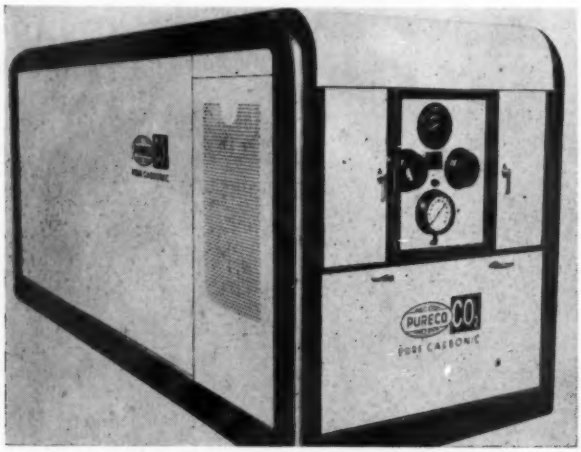
A. F. Maxfield, sales manager of United States Testing Company, Inc., says his firm does not now have any facilities utilizing CO_2 but expects to have them in the near future.

"We are definitely interested in the potential offered by this relatively inexpensive means of reducing ambient temperatures around a test item in a short time," Mr. Maxfield says. "We have conducted a limited series of tests and feel certain that in certain applications that liquid CO_2 is an ideal method."

These are typical of the replies received by Environmental Quarterly in a broad survey of manufacturers and users of CO_2 equipment. In the same breath many of them spoke of other, similar refrigerants, liquid nitrogen being mentioned most often. "It would seem," wrote Dale J. Missimer, vice president of Missimers Incorporated, "that your article should be called 'Expendable Refrigerant Cooling Systems and Their Application.'"

Despite favorable reports and widespread experience, so many have yet to try CO_2 testing as to justify its being described as a new technique. "After the IEE exposition in Chicago (last April), we came to the conclusion that many persons are still not familiar with the basic operation of carbon dioxide in low temperature testing," says John P. Antolak, director of carbon dioxide technical sales for Liquid Carbonic Division, General Dynamics Corp.

Generalizations on a complex subject necessarily run the risk of being deflated. Were it necessary, however, to generalize the advantages of CO_2 in environmental testing, three words might do it: Versatility, speed and economy. But each must be considered within the framework of the technique's limitations.



Six-Ton Liquid Carbon Dioxide Receiver

Adaptable to Special Need

"We are continuously confronted with test objects in such a variety of sizes and shapes that it is not always practical to construct facilities that will accommodate every one," U. S. Testing's Maxfield says. "With liquid CO_2 as the refrigerant, temporary structures are easily fabricated. For short term exposures, very light structures can be used, with considerable saving in cost and preparation time."

Monroe Seligman, president of Tenney Engineering, Inc., one of the oldest and largest firms in the environmental chamber business, sums it up this way:

"Liquid CO_2 provides for very rapid temperature changes which would be prohibitive in cost when attempted by mechanical means. Some clients have considered the use of CO_2 for rapid pull down applications only and then have available a mechanical refrigeration system to take care of the cooling after pull down has been accomplished."

Costs enter into two other off-the-beaten-path factors

(Continued on Page 18)

Expendable vs. Mechanical—A Comparison

By DALE J. MISSIMER, Vice President, MISSIMERS INCORPORATED

	Dry Ice (Expendable)	Liquid CO_2 (300 PSIG - 0° F.) (Expendable)	Liquid Nitrogen (Expendable)	Mechanical Refrigeration
ADVANTAGES	LOWEST cost expendable coolant EASILY used for achieving —90° F. quickly DIRECT application gives inert atmosphere LOW capital investment LOW service and maintenance costs LITTLE power and no water or other utilities FAIRLY easy to control if used with secondary refrigerant WIDE temperature ranges are possible—not limited to upper temperature of 400° to 500° F. as with mechanical refrigerant	LOW capital cost EASILY controlled for temperature and for capacity NO storage losses LITTLE power required for operation, no water or other utilities LOW handling costs DIRECT injection gives inert atmosphere LOW maintenance and service costs EASY to achieve —90° F. NO limitations of upper temperatures for chamber QUICKLY takes up large cooling load increases	EASILY used for direct or indirect cooling system, with N_2 or air atmosphere EASILY used at one atmospheric pressure for liquid-vapor phase refrigeration—no solid phase problems CHAMBER free of frost and snow inside when direct injection used EASILY produces temperatures to —300° F. TEMPERATURE and capacity from room ambient to —300° F. easily controlled. ATMOSPHERE can be inert if desired NO limitation for upper temperature of chamber LOW capital cost LOW power requirements LOW maintenance costs MODEST handling costs CAN easily take up large load increases NON-TOXIC	LOW operating costs LOW handling costs EASILY controlled for both temperature and capacity ONLY electrical power required for air cooled systems NOT dependent upon supply of materials which are not always convenient to obtain. NO storage losses CAN produce lower temperatures than CO_2 NO ventilation required for expended vapors ATMOSPHERE is air EASILY used for altitude test chambers without necessity of secondary refrigerant SUITABLE for humidity control systems USUALLY most economical down to —40° F. depending on usage GOOD heat transfer characteristics NOT hazardous to operating personnel
DISADVANTAGES	RELATIVELY high handling costs MORE difficult to control temperature than liquid expendable refrigerants, for direct application. DIRECT application results in snow in chamber, and atmosphere is not air MUST have ventilation or provide for exhausting CO_2 vapors HIGHER losses in storage DIFFICULT to control capacity automatically with changes in loads, even with indirect system LOWEST practical temperature is —90° to —100° F. RELATIVELY poor heat transfer characteristics NOT very economical down to —30° or —40° F. SLIGHTLY toxic CAPITAL investment higher if used with secondary refrigerant	RELATIVELY high operating costs FOR direct injection, snow may be objectionable ATMOSPHERE not air VENTILATION required for larger flow rates EXPANSION devices subject to plugging FOR direct injection, sublimation takes place at only one low temperature (approx. 109.4° F.), making control at moderate temperatures more difficult REQUIRES storage receiver space NOT particularly economical down to —30° or —40° F. LOWEST practical temperature is —90° to —100° F. TRIPLE point of —69.9° F. presents major problem because can't be used as liquid vapor phase refrigerant at near atmospheric pressure SLIGHTY TOXIC	STORAGE and/or availability can present problems RELATIVELY high operating cost unless there is large monthly usage SOMEWHAT hazardous if spilled on human beings SOME ventilation may be required when large amounts are used GENERALLY not economical for cooling at temperatures above —100° F. HEAT transfer at high temperature differentials is poor CONTROL methods or devices slightly more complex and expensive than for liquid CO_2 STORAGE costs generally higher than for liquid CO_2 or dry ice	HIGHER capital costs MORE floor space required HIGHER maintenance costs MORE skilled personnel required for service SLOWER cooling rates generally WATER generally required for larger systems PRACTICAL upper temperature limit of 400° to 500° F. for chamber without special temperature isolation provisions INERTING requires separate source of vapor MORE electrical power required NOT economical for infrequent low temperature tests of short duration DEFROSTING of heat exchanger surface can be a problem

The Plus and Minus of CO_2

(Continued from Page 16)

cited by Mr. Seligman for selecting CO_2. Use of CO_2 rather than mechanical refrigeration puts a minimum drain on short power supplies in remote locations, he points out, and some organizations find it easier to get operating funds rather than allotments for capital expenditures. For example, a chamber was quoted recently to a major aircraft manufacturer at a cost in the neighborhood of $100,000—as contrasted with $500 per use day of liquid CO_2 costs.

"The use of liquid CO_2 permits the customer to buy virtually a bare chamber at very nominal cost with reasonably high operating costs occasioned by CO_2 consumption," Mr. Seligman says.

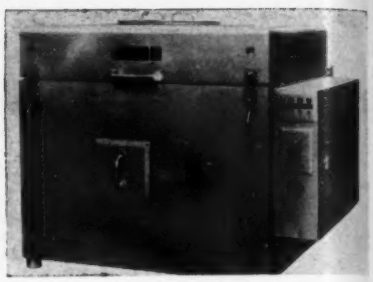
For Testing at Infrequent Intervals

Thus a CO_2 chamber would seem to be indicated when testing needs are limited. Discussing an eight-cubic-foot unit his company designed for use with both horizontal and vertical vibration exciters, Rolland S. Jamison, sales manager of Harris Refrigeration Co., observed that the cost of the liquid CO_2 is very high when the chamber is used for tests of long durations.

"We must agree, however, that there are cases where the use of CO_2 seems to be justified when compared with mechanical refrigeration for testing at infrequent intervals," Mr. Jamison said.

A similar view is offered by Mrs. L. M. Doherty, of Cincinnati Sub-Zero Products. "For continuing operation as compared to intermittent use, mechanical refrigeration would, over a period of time, prove the most economical," she says.

Mrs. Doherty notes a CO_2 disadvantage in "the need for having a quick, or nearby supply of the refrigerant."



Liquid nitrogen chamber, —300° to +700° F., by Bemco, Inc., is used for reentry studies.

Chambers utilizing CO_2—or other gases—are as broad and as long as any other cold box. A major feature is the elimination of machinery that accompanies conventional chambers. "No moving parts except for one valve" is the way Associated Testing speaks of its designs.

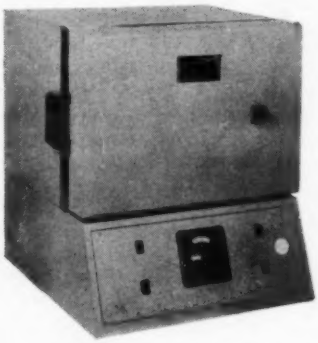
CO_2 units can have high temperature and other conditions, too, and can be closely controlled with appropriate programming instruments. Special chambers are not uncommon. Cincinnati Sub-Zero Products, for example, has designed one for high-low temperature testing of wire and cable used in electronic components. The CO_2 counterpart of a mechanically refrigerated wire test cabinet "for users who may have intermittent use of such equipment or who have ready access to CO_2," the chamber is 12 x 72 x 14 inches deep and has a range of —100° to +200° F.

Liquid Nitrogen and Helium

Liquid nitrogen and liquid helium have their boosters too.

"Liquid nitrogen in particular has come into its own recently as its cost per BTU is approximately equal to

CO_2 CHAMBERS



-100° → 600° F
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Direct discharge of liquid carbon dioxide provides instantaneous cooling in test chambers. You need only minutes, instead of hours, to get a rapid pull-down to —100° F.

POSITIVE CONTROL

Careful design of your Cardox CO_2 System permits reliable maintenance of low temperatures. Accuracies of ±½ of 1°F. are possible.

NO CAPITAL INVESTMENT

Cardox will supply and maintain your storage unit on a "user contract" basis, and you pay for only the CO_2 you actually use.

NO WASTED CO_2 VAPOR

An exclusive Cardox Re-Cycling System can assure you of a consistant supply of liquid carbon dioxide. It eliminates vapor problems which can interfere with temperature control accuracy, reduce refrigeration effect and cause a waste of carbon dioxide.

A COMPLETE CO_2 SUPPLY

A Cardox CO_2 storage unit can be installed anywhere, inside or outside, in whatever size you require . . . in pounds or tons of carbon dioxide. And CO_2 can be furnished wherever you need it . . . Cardox offers a bulk storage unit to supply many or large test chambers, or completely portable tanks for mobile applications.

USE ONE CHAMBER FOR HOT AND COLD TESTING

From +1000°F. to —100°F. is possible in the same test chamber. When you use Cardox carbon dioxide for cold testing there is no problem with high temperature . . . no coils to burn out . . . no refrigeration fluid to evaporate or overheat.

COLD TEST ENGINEERING ASSISTANCE AND SERVICE

Cardox offers you a complete engineering service in planning the most efficient use of carbon dioxide for cold tests. Detailed experience with the test engineer's problems means Cardox can offer you valuable assistance.

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DIVISION OF CHEMETRON CORPORATION CHEMETRON
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A Liquid Carbonic CO_2 installation at Stewart Warner, Indianapolis, for low temperature testing of jet fuel. It was ready for operation about one month after receipt of contract.

CO_2 and it provides temperatures down as low as —320° F.," says Bemco's Stuart Giles, adding:

"Nitrogen has other advantages in that it is easier in some ways to handle. CO_2 has a tendency to turn to dry ice when it is sprayed into a chamber in large quantities."

Some of the disadvantages of CO_2, such as the effect of the vapor when it may combine with moisture to form a mild carbonic acid have been overcome, of course, by not immersing the test specimen in the refrigerant. Instead, secondary systems are used in which the expendable refrigerant chills a brine solution which, in turn, chills the chamber. Advantages of this approach include close temperature control by use of a modulating control system, use in altitude as well as "sea level" chambers and the fact that a central souce can supply brine to several chambers.

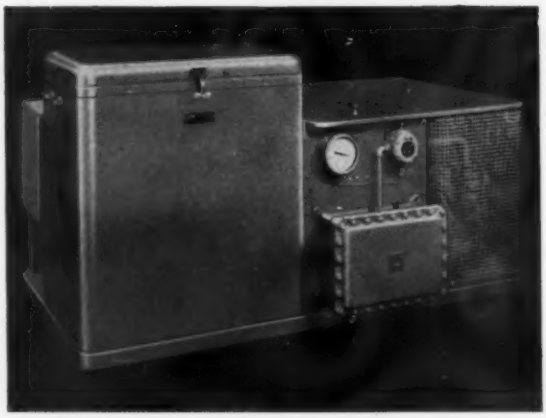
A final consideration in deciding on CO_2 is availability. The compressed gas manufacturers insist, of course that this is no problem. With nationwide distribution networks and a variety of storage tanks, this would seem to be so, and tanks may be supplied free of charge.

CO_2 LIQUID—THE IDEAL EXPENDABLE REFRIGERANT

by D. B. Clapp, Jr.
Regional Sales Manager
Pure Carbonic Company, Los Angeles

The technique of discharging carbon dioxide liquid through an expansion orifice has been developed and refined as low temperature refrigeration requirements have become more complex.

When CO_2 liquid is discharged through a nozzle to atmospheric pressure it flashes instantly into a mixture of finely divided particles of CO_2 snow and cold CO_2 vapor in temperature ranges down to —109°F. The CO_2 liquid can be expanded directly into the environmental chamber or into a sublimation tank containing a secondary system



Production chilling of stabilizing shafts utilizes this Cincinnati Sub-Zero unit, with temperature range of —70° to —150°. Chills 150 lbs. of steel hourly . . . 4000 BTU/hr at —120°F.

Write today for full-line catalog. Or describe your requirements so our Engineering Department can make recommendations.

CHOOSE THE PIONEER

CINCINNATI SUB-ZERO PRODUCTION and CHILLING EQUIPMENT

For 20 years we have been building low temperature testing and storage units. As the most experienced manufacturer in the field today, we take pride in our record for 100% reliability . . . and for building a little more into every unit produced.

Member: Environmental Equipment Institute

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LOW COST CENTRIFUGE

for large-quantity acceleration test programs

Genisco Model A903 features simplified operating procedures; rugged construction... for fast, accurate testing to MIL-E-5272A, Procedure II

Although the A903 is a simple, low cost centrifuge, it has many features found in more sophisticated machines, *plus* unique features which particularly suit it for production-line testing and evaluation programs.

SIMPLE OPERATION—Except for an on-off switch, controls are limited to a single handwheel which controls table speed. Chance of human error is reduced to a minimum. Test personnel can learn its operation in minutes.

SPEEDS TESTING—24" diameter mounting-table will accommodate several test objects. Arranged symmetrically, they can be subjected to acceleration forces simultaneously.

RUGGEDLY-BUILT—Virtually immune to operational abuse. Will operate for long periods without maintenance as demanded for production test programs.

0.5% ACCURACY—Constancy of rotation of the mounting-table is within 0.5%, including wow and drift. Table rotation speed can be measured electronically within ±1 count.

BRIEF SPECIFICATIONS

G-Range: 1 to 1,000 g's in five standard ranges, infinitely variable

G-Pound Capacity: 2,500 g pounds, maximum

Constancy of Rotation:

Wow: 0.5%, maximum

Drift: 0.2% of rate per minute, maximum

Speed Indication Accuracy:

Tachometer: ±1¼%

Magnetic Pickoffs: 60 tooth pickoff gear standard; 600 tooth gear optional. Pulses are fed to a front panel coaxial receptacle for use with any standard electronic counter.

Vibration Isolation: 0.1 g in any plane, at any speed

Test Object Dimensions: 8" high (24" diameter circular platform)

Slip Rings: 8 standard, 10 amp. maximum

Write for complete technical information and prices.

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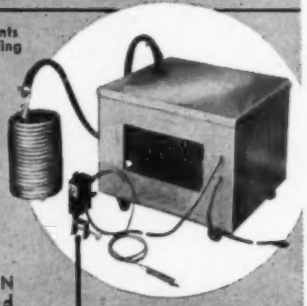

CONTROLS WITHIN ±0.15° C. NEW and PROVEN principle (CONSTANT-FLOW) permits rapid cycling, close temperature control, longer compressor and control life. Use of expansion valve dryer-strainer system assures reliability and quality. Ideal for containers providing cooled water or other liquid media, for auxiliary apparatus, etc.

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(B) −23° C. to +5° C.

- Stainless Steel Cabinet
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MANUFACTURERS AND DESIGNERS
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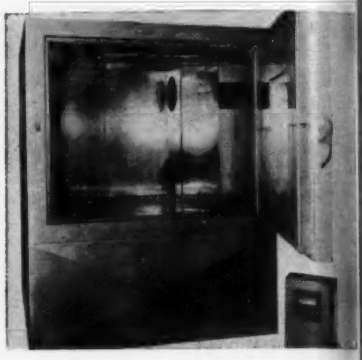

Missimers Incorporated's 80 cf, dry ice-cooled temperature chamber reaches from −90° to +600° F.

heat transfer fluid which is, in turn, circulated through heat exchangers inside the facility.

In either case extremely rapid pull down from ambient is achieved by the positive action of this expansion. The application becomes fully automatic when a solenoid valve, activated by a thermostat, controls the procedure. The rate of refrigeration is determined by the size of the nozzle or orifice.

The solenoid valve and nozzle size are important factors in the technique. Valve action must be rapid and positive to insure close temperature control. A pneumatic type is usually recommended for medium to heavy flows.

The orifice size must be properly engineered to insure maximum efficiency. If the nozzle is too small the rate of cooling will be slow and inadequate; if it is too large excessive snow will accumulate in the chamber. A manifold of jets may be employed to handle "pull down" and peak loads on larger chambers, and, in some cases, a dual system is installed with part of the jets cutting out after peak loads have been absorbed. The remaining nozzles handle normal heat loss.

Costly Hours Saved

Acting as a supplement, CO_2 not only fulfills many environmental requirements where thermal shock is indicated, but also saves many costly hours in normal hot-cold cycle tests. Practically 100 per cent operation is assured. Down time for mechanical failure is at a minimum and breakdowns are eliminated. Mechanical units, relieved of burden some pull down loads, operate with greater efficiency.

"Dry ice" chambers have been converted to or supplemented by carbon dioxide liquid—generally in a large test facility in which a sublimation tank is utilized. As the sole refrigerant, the liquid, of course, eliminates handling of dry ice and charging and re-charging of chambers. This is especially useful and saves personnel costs when a test is scheduled overnight and over weekends.

In addition, dry ice sublimation losses during storage are eliminated. CO_2 liquid is used on a demand basis, and only the exact amount of refrigeration required is expended. It is stored indefinitely in a refrigerated receiver without loss.

In a secondary system, CO_2 liquid permits smaller sublimation tanks and less transfer fluid is required. In some applications CO_2 is injected directly into the line carrying the secondary refrigerant. Great efficiency is achieved since the line itself becomes the sublimation tank, and injection of CO_2 in the direction of flow enhances circulation.

A relatively small vapor release and surge tank may be substituted just ahead of the circulating pump in this circumstance.

Flexibility is another advantage of CO_2 liquid. Distribution to any point in a test laboratory is achieved by a recirculating supply system or use of portable 1000-lb storage

(Continued on Page 54)

Environmental Feedback..

TESTING DIVISION
Stressing the Engineering approach in Environmental, Qualification and Reliability Testing

Associated

MANUFACTURING DIVISION
The quality line of Environmental Chambers and Test Equipment

The skill and know-how gained from the coordination of Associated's two divisions through "feedback" of information assures the proper utilization of test equipment within the Testing Division and the proper design of environmental test equipment within the Manufacturing Division.

Write for illustrated literature!

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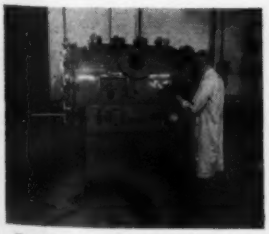
Temperature-Altitude-Humidity −300°F to +500°F, 200,000 ft., 5% to 100% RH, in one of more than 30 chambers available for your testing.

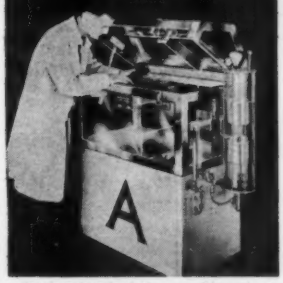
Sawtooth shock test being performed on a Shock Test Machine developed by Associated.



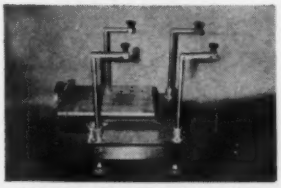
Explosion-proof testing in accordance with specifications MIL-E-005272B, MIL-E-5272C, MIL-E-5422D, etc.

Reliability testing being performed using automatic check out panels.

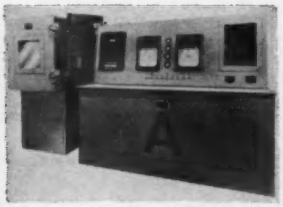
MANUFACTURING DIVISION



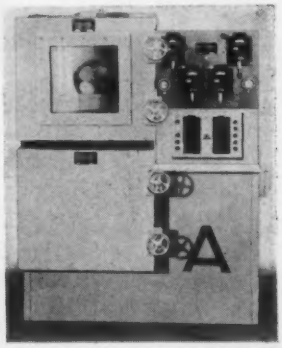
All Lucite Salt Spray Chamber built to perform tests in accordance with specifications MIL-E-5272A, QQ-M-151A, MIL-STD-202A, etc.



Auxiliary Vibration Table (Slippery Table) a complete line, adjustable in height, for use with any vibration machine.



Temperature-Altiude Test Chamber for environmental testing within the range of −300°F to +1200°F and from sea level up to 350,000 feet.



High temperature—low temperature chambers available in single or dual units for testing range of −300°F to +1200°F.

ASSOCIATED TESTING LABORATORIES, INC.

Testing Division • Manufacturing Division

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LITERATURE FOR ENVIRONMENT...

Harris Refrigeration Co., Cambridge, Mass., now in its 25th year, describes a new series of temp-hum chambers from a 2 cf portable to a 10 cf production test model in a two-color catalog folder. (Circle EQ RSC #38)

* * *

Consolidated Vacuum Corp., Rochester, N. Y., pictures and gives full data on its complete line of high vacuum valves, baffles and traps in a 28-page, two-color brochure, punched for ring binding. (Circle EQ RSC #39). Another colorful pamphlet describes CVC's HY-6500 shock tester for repetitive producer-line testing of small components. (Circle EQ RSC #40)

* * *

American Research Corp., Farmington, Conn., has a new 12-page catalog of its environmental test equipment from walk-in rooms with three-ton doors down to 18" diameter bell jars. (Circle EQ RSC #41)

* * *

Itemlab Inc., Port Washington, N. Y., has a three-page gold and white folder describing its research, design and development program as well as its complete product testing facilities. (Circle EQ RSC #42)

Missimers, Inc., Glendale, Calif., offers a bulletin on its one-cubic foot bench-type temperature test chamber, Model FT1, which has a range of —100° to +350°F. (Circle EQ RSC #43)

* * *

United States Testing Co., Hoboken, N.J., tells what its materials evaluation division can do in six-page Bulletin 5902. The division's four major laboratories are: Metallurgical, metals chemistry, plastics evaluation, and physical testing. (Circle EQ RSC #44)

* * *

Rempe Company, Chicago, has published a new edition of its Engineering Data Book. Heat transfer coefficients for all heating and cooling problems involving pipe or fin coils are tabulated in the 48-page volume, originally produced in 1947. Depressant factors for coils in simulated high altitude conditions are a new feature. (Circle EQ RSC #45)

* * *

Tele-Dynamics, Inc., Philadelphia, describes its environmental test facilities—vibration, temp., hum., alt., acoustic noise, shock, radio interference and others—in Bulletin 859. Primarily for TDI use, the lab is also available to others. (Circle EQ RSC #46)

General Vacuum Corp., East Boston, Mass., gives a quick summary of its high vacuum retort furnaces, altitude chambers, vacuum pumps, leak detectors and valves in a series of illustrated, ring-punched leaflets. (Circle EQ RSC #47)

* * *

General Electric Co's., Missile and Space Vehicle Department, Philadelphia, has put out a 24-page, profusely illustrated two-color booklet describing its advanced facilities for structural testing of missile and aircraft components. (Circle EQ RSC #48)

* * *

Leeds & Northrup Co., Philadelphia, has released a newly-revised 52-page Catalog EN-S2 on its line of thermocouples and thermocouple components and accessories. It offers recommendations as to their best uses. (Circle EQ RSC #49)

* * *

Fischer & Porter Co., Hatboro, Pa., is distributing spec sheets on its 1202 series 4-inch strip chart miniature recorders and 1212 series miniature recording control stations for process variables. (Circle EQ RSC #50)

* * *

Traid Corp., Encino, Calif., has followed up its "Camera Selector" with a companion "Lens Selector," describing over 57 different lenses available to motion picture and sequence data camera users. (Circle EQ RSC #51) Traid also has a bulletin on its new high speed 70mm camera which makes 2¼ x 2¼" pictures at 360 frames per second. (Circle EQ RSC #52)

* * *

LaPine Co., Chicago, has a laboratory apparatus review and a special purpose cabinet catalog showing vacuum ovens and advanced style humidity cabinets. (Circle EQ RSC #53). LaPine is also offering a second edition of its catalog on laboratory freeze-drying, high vacuum and related equipment. (Circle EQ RSC #54)

* * *

Dow Corning Corp., describes its new silicone dielectric potting gel in a four-page illustrated brochure. The gel provides a transparent, dimensionally-stable cushion protecting assemblies from vibration, shock, moisture, dirt and dust from —60° up to 200°C. (Circle EQ RSC #55)

* * *

Office Of Technical Services, U. S. Department of Commerce, Washington, 25, D. C., has placed on sale at $3.50 a 205-page publication, PB151-649, "A Modern Dynamic Approach to Product Development" by Sidney Sobelman, chief of the Special Analysis Branch of the Army's Picatinny Arsenal.

FREEDOM

Our inertial guidance systems utilize two-degrees-of-freedom gyros. If you would like to do advanced work with these and have had at least a year of engineering experience, please write Mr. C. T. Petrie, Manager, Research & Engineering Staff.

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Beverly Hills, California

Government Publications

Almost daily the U. S. Department of Commerce releases a number of technical reports for use by industry. These documents are sold through the department's Office of Technical Services, Washington 25, D. C. Here are some recent releases and their prices:

(ARDC—Air Research and Development Command)

(RADC—Rome Air Development Center)

(WADC—Wright Air Development Center)

"Acoustic Emission under Applied Stress," by B. H. Schofield, R. A. Bareiss and A. A. Kyrala, of Lessells and Associates, Inc., for WADC. The research is reported to have verified the existence of the "acoustic emission" phenomenon and to have shown a possible connection between emission and dislocation action. 39 pages. Order No. PB 151215, $1.25.

"Ultra High Temperature Miniaturized Power Transformers and Inductor Materials, Vol. 1 and 2," by H. B. Harms and J. C. Fraser, General Electric Co., for WADC. The report identifies electronic transformer materials which appear best suited for use at 500C and under intense nuclear radiation. 476 pages. Order No. PB 151141, $6.

"Test and Evaluation of the MA-5 Air Conditioner," by J. L. Hahn and D. J. Scarafile, RADC. The unit, used by the Air Force for cooling electronic equipment, was rated extremely reliable, efficient, compact and mobile. 29 pages. Order No. PB 151039, $1.

"The Theory and Operation of a Dynamic Tester for Evaluating Package Cushioning Material," by S. M. Krakover, WADC. The report discusses refinements in the design of Wright's packaging cushion tester, several redesigns of the dropping carriage and results of round robin analyses of dynamic testers used by a number of commercial labs. 19 pages. Order No. PB 121692-S, 75c.

"New Medium for the Protection of Electronic Equipment against Shock and Vibration," by R. H. Jacobson, WADC. The medium is a multi-layer grid of 3/32-inch Teflon rods embedded in a matrix of silicone rubber. Fifty-seven materials and combinations of materials were investigated. 153 pages. Order PB 151005, $2.75.

"Study of Ultra High Temperatures," by A. V. Grosse and A. G. Streng, of Temple University, for the ARDC. The study dealt with the combustion of pure ozone to oxygen and with the combustion of pure ozone with various fuel gases. Pure ozone and premixed mixtures of ozone and combustible gases were burned without detonation. 100 pages. Order No. PB 131732, $2.50.

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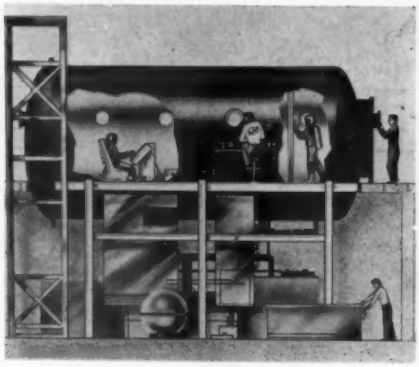
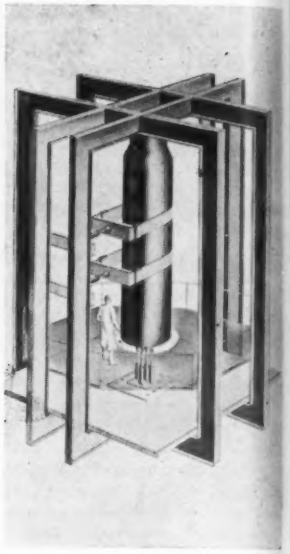
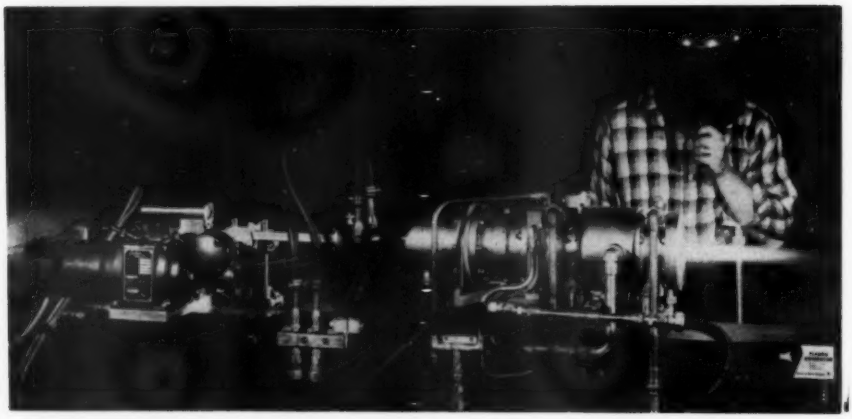


HEAVENLY CHAMBER. Here is rendition of the 150-mile ionosphere simulation chamber Republic Aviation Corp. is planning for its $14 million astronautics research center at Farmingdale, N. Y. The highest so far is said to be about 38 miles for man and 85 miles for components. Tenney Engineering, Inc. is the chamber maker.

COMPLEX GRADUATE. Jack A. Ling (left), reliability engineer at the Sperry Utah Engineering Laboratory, Salt Lake City, is the 50th graduate of MB Electronics' series of 10-day seminars on complex motion vibration testing. George H. Mett'er, president of MB, presents a diploma.



MEASURE OF A POLARIS. A 35-foot high, 20-square foot structural test fixture to simulate all stresses encountered in 1½ seconds after launching by a Polaris solid propellant missile motor is being constructed by The Rucker Co., Oakland, Calif., for Aerojet General Corp. Loading equipment may be positioned in any desired direction.



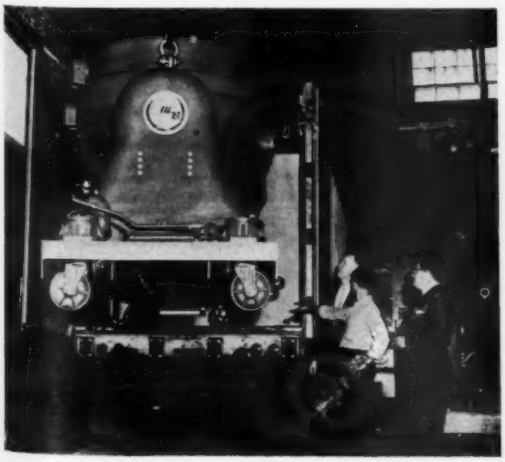
HEAT'S ON. At General Electric, Philadelphia, flame of more than 5,000° F. is aimed (left, top) at a sample of new nose cone protective material which GE says has withstood temperatures of more than 15,000°—greater than the heat of the sun. The material is an organic plastic substance said to be more economical than protective coatings now in use. At left, bottom, is Avco Research and Advanced Development's plasma generator capable of up to 18,000° F. The first production model has been delivered to NASA's Jet Propulsion Laboratory in Pasadena, Calif. Originally perfected by Avco for testing materials in Titan and Minuteman reentry vehicles, the device can be used to simulate closely environmental conditions of air enthalpy, pressure and heat flux associated with reentry, according to Avco. (Circle EQ RSC "E" for plasma generator information.)

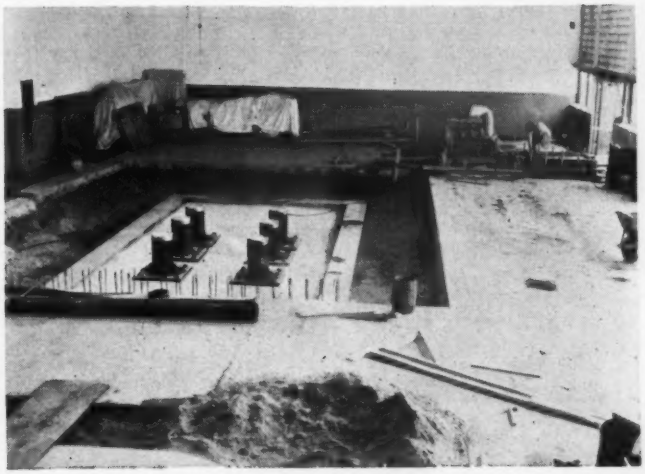
Products, Places and Ideas...

ATTRACTIVE IN ANY ENVIRONMENT. Minnesota Mining and Manufacturing Co.'s new "Paklon" film tape No. 361 is said to resist the advances of water, acids, alkalies and other strong solvents, as well as wide temperature ranges. The hammer helps illustrate its tensile strength of 30 lbs. per square inch. The young lady helped get the picture into print.

COMMERCIAL APPLICATION. Slab of polyurethane foam is being placed in an environmental chamber for humidity aging test at the England Co.'s Baltimore plastic division plant. The cabinets by Labline, Inc., Chicago, operate continuously around the clock at temps up to 210° F and humidities up to 95%. (Circle EQ RSC "D".)

MOVING EXPERIENCE AT SPERRY GYROSCOPE. Only a sign guiding overwidth trucks suffered as Sperry's new, 65-ton space chamber wended its two-section way from Tenney Engineering, Inc., Union, N. J., to Lake Success, N. Y. But inside the lab (right) there was trouble until braces welded to the back of the chamber section gave the crane a better grip. Then the upright section was skidded onto the waiting foundation of 90 tons of cork-insulated concrete (right, bottom). Meanwhile, MB Electronics dispatched a 92,000-ton vibration system from New Haven (below) to be mounted on the metal stanchions in the foundation. Two exciters in the system can each handle specimens weighing up to 2,500 lbs. at up to 10 g acceleration under simulated conditions of 120,000 feet, −100° to +350° F and either air or liquid cooling. (Circle EQ RSC "B" for information on the chamber, "C" for the shaker system.)





People You Know...

CHANGING ENVIRONMENTS

WILLIAM L. VANDAL, formerly engineering group leader of NORTH AMERICAN AVIATION'S AUTONETICS division environmental lab, has become manager of central environmental testing at AERONUTRONIC, a FORD MOTOR CO. division, in Newport Beach, Calif. He is executive vice president of the Institute of Environmental Sciences.

• • •

E. ROBERT BRITTON, of E. ROBERT BRITTON & SONS, St. Petersburg, Fla., has been granted a doctor of science degree. His doctoral thesis was: "Characteristics of a Multi-Degree-of-Freedom Auxiliary Vibration Table." He is editor of "Suncoast Signal," the Florida west coast IRE bulletin.

Garber

Britton

Conover

Vandal

Nissen

Herold

MAX GARBER, manager for the past six years of CONSOLIDATED ELECTRODYNAMICS CORPORATION'S Eastern regional office in Philadelphia, has become director of the company's newly-established separate marketing organization in Rochester, N. Y. The Rochester division will supply high-vacuum and environmental test equipment through district sales offices in 10 cities. The new managers and their offices are: **CHARLES P. HOLDERBAUM,** Rochester; **RALPH A. BROSMAN,** Boston; **HERBERT C. WALDECK,** New York (Hasbrouck Heights, N. J.); **WILLIAM C. CAMERON,** Philadelphia; **ARTHUR A. CHAMBERS,** Atlanta; **CHESTER NORTHUP,** Columbus; **FRED E. EICHMANN,** Chicago; **ALTON J. WANAMAKER,** Beverly Hills; and **ROBERT O. JOHNSON,** Palo Alto. The manager for the Albuquerque office is to be named.

• • •

EDWARD W. HEROLD, longtime director of RCA's electronic research, has become vice president for research of VARIAN ASSOCIATES. A distinguished scientist, he wrote the Encyclopedia Britannica's article on electron tubes, has published more than 30 technical papers and holds 40 U. S. patents on tubes and semi conductors. Herold forsakes RCA's Princeton, N. J., lab for Palo Alto, Calif., where he will direct long-range research for Varian, an 11-year-old manufacturer of klystron tubes and other precision electronic devices.

• • •

FRANKLIN H. DONNELL, chairman of CONSOLIDATED ELECTRODYNAMICS CORPORATION'S finance committee for nearly 15 years, has been named senior vice president for finance. He will be responsible for the company's financial policies and the administration of all internal financial affairs. He will also serve as vice chairman of the newly formed executive committee, which has overall supervision of CEC and its subsidiaries. Donnell was vice president of a brokerage firm and a member of the Los Angeles Stock Exchange when he was 22. Other promotions and changes at CEC include: **DR. CLIFFORD E. BERRY,** appointed director of engineering for the Analytical & Control Instrument division (he was assistant director of research); **DR. CHARLES F. ROBINSON,** now associate director of research, up from chief research physicist; **WILLIAM F. JOHNSON,** assistant director of the Electro Mechanical Instrument division, a new post shifting him from director of sales engineering; and **HOWARD B. LEWIS,** chief engineer of the Transducer division. Lewis, who will head a new five-group engineering organization, joined CEC as a development engineer in 1952.

• • •

CARROLL STOECKER, Eastern district sales manager of THE GARRETT CORP., has been made assistant manager of the company's Aero Engineering Division with headquarters at Mineola, N. Y. He joined the company in 1950 as a sales engineer.

• • •

JOHN E. GABRIELSON is THE BRISTOL CO.'s new sales engineer in Salt Lake City. He has been with the company since 1956 in the application engineering department at the Waterbury home office. He will handle the Salt Lake City-Idaho Falls area.

• • •

PAUL A. NISSEN has become sales engineer for the Isomode division, MB ELECTRONICS, succeeding **FRED BRADSTREET** who earlier this year went up to division manager. Nissen will be responsible for sales and application engineering for MB's broad line of vibration isolating products. He joined MB in 1956 and worked on design problems.

• • •

GEORGE M. ROUZEE has the newly-created job of sales manager in the western development labs of PHILCO's Government and Industrial division. With Philco less than a year, he was G & I government sales manager for advanced military systems. He was formerly at SPERRY GYROSCOPE CO. as sales manager for the air armament and special missile systems. He will be succeeded by **KENNETH J. EVANS,** formerly plans manager, advanced design division of MARTIN COMPANY.

• • •

LAUREL E. COOLY has been transferred from THE RUCKER COMPANY'S Oakland headquarters to take charge of inside sales at the company's Portland, Ore., facility. The Portland office of the big pneumatic and hydraulic parts distributor was recently moved to new and larger quarters, doubling the warehouse space.

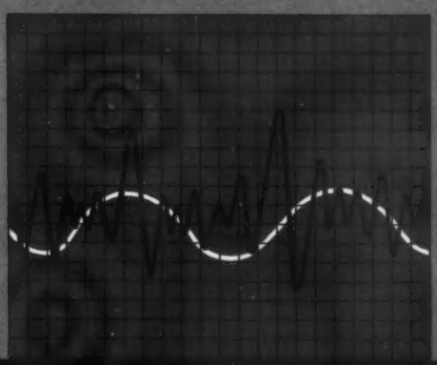
• • •

GERRET B. CONOVER, formerly assistant chief engineer for Propulsion Test Equipment division, PENN-TEXAS CORPORATION, has been appointed to the similar job with PROPULSION TEST FACILITIES, INC., an affiliate of MB ELECTRONICS.

Testing a telemetry component for the Polaris program on a Random Wave Vibration System. Lockheed Missile and Space Division, Sunnyvale, Calif.

LING

ATCHED VIBRATION TEST SYSTEMS



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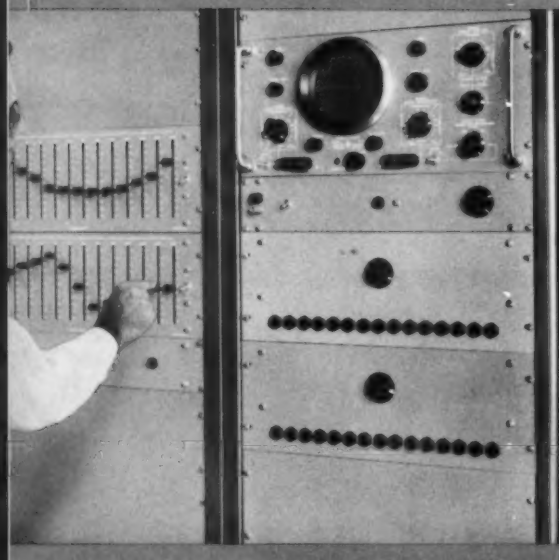

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Operating as a system, it reduces random wave set-up time to a few minutes—provides easier and more accurate equalization because the operator has a continuous picture of the shaker spectrum, and makes corrections with simple level adjustments.

Better equalization results, and overstress of specimens during set-up is prevented.

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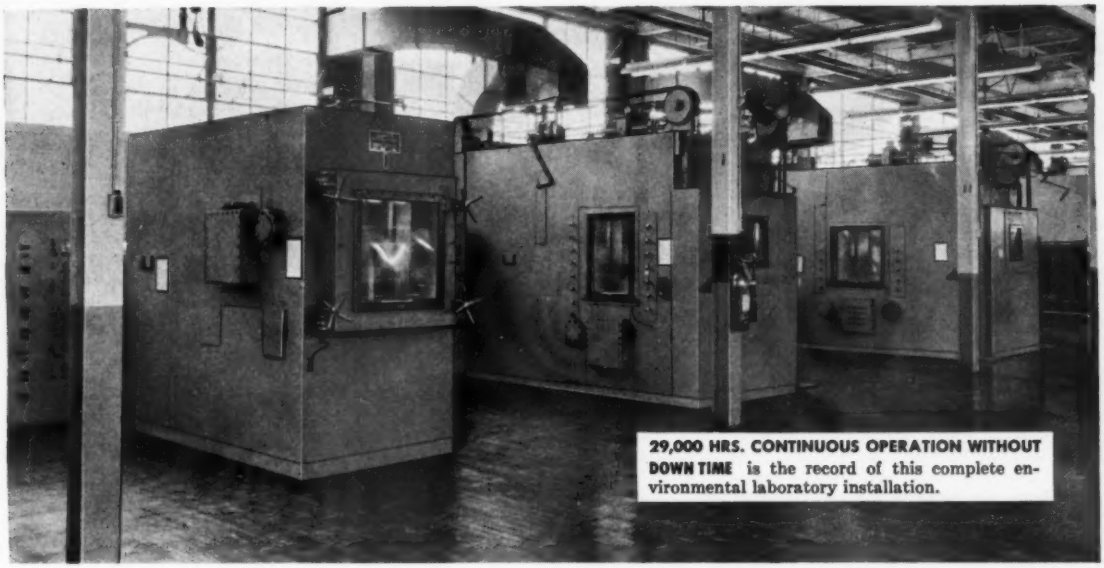

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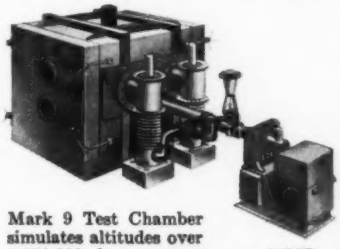

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THE SEISMIC SHOCK AND VIBRATION PICKUP — Part II

Practical vs. the Ideal

by John H. Armstrong and George Stathopoulos
Naval Ordnance Laboratory
White Oak, Silver Springs, Md.

Practical shock and vibration instruments are at most only approximations of the idealized system postulated for purposes of analysis, since many of the assumed conditions cannot be entirely realized. Principal deviations from the idealization and their qualitative effect upon performance should now be considered.

THE ASSUMED single-degree-of-freedom system includes a massless, linear elastic element supporting a rigid mass within a rigid case. The sensing system is also theoretically linear in its translation of case-mass motion to output signal.

A distortionless pickup will have a constant calibration factor or ratio of the amplitude of the output signal to the amplitude of the corresponding parameter (acceleration, velocity, etc.) of the exciting motion. If the calibration factor varies with the amplitude of the exciting motion, amplitude distortion is present. The principal cause is non-linearity in the pickup, either in the force-deflection relationship of the elastic element or in the signal-displacement or signal-velocity relationship of the sensing scheme.

While similar in effect upon the calibration factor, these two sources of non-linearity may be different in effect upon pickup usability. Non-linearity in the sensing system can be compensated for by a correction factor determined by calibration of the sensing system alone under static conditions (in a centrifuge or by the application of known deflections, for example). Since the natural frequency of the instrument is related to the stiffness of its seismic system, marked non-linearity in the mechanical system results in a different effective natural frequency of the

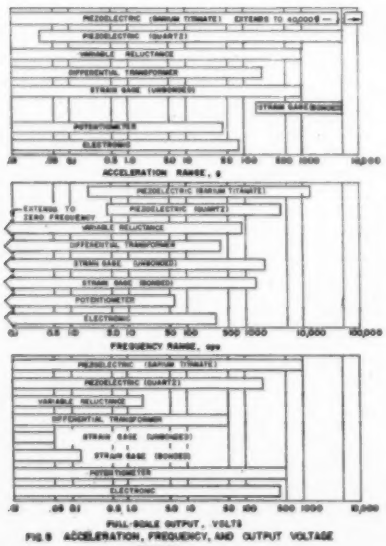

FIG. 8 ACCELERATION, FREQUENCY, AND OUTPUT VOLTAGE RANGES

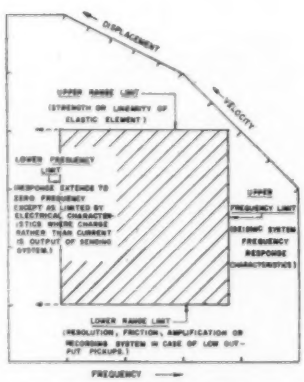
DISPLACEMENT
VELOCITY
UPPER RANGE LIMIT
(STRENGTH OR LINEARITY OF ELASTIC ELEMENT)
LOWER FREQUENCY LIMIT
RESPONSE EXTENDS TO ZERO FREQUENCY EXCEPT AS LIMITED BY ELECTRICAL CHARACTERISTICS WHERE CHARGE RATHER THAN CURRENT IS OUTPUT OF SENSING SYSTEM.)
UPPER FREQUENCY LIMIT
SENSING SYSTEM FREQUENCY RESPONSE CHARACTERISTICS)
LOWER RANGE LIMIT
(RESOLUTION, FRICTION, AMPLIFICATION OR RECORDING SYSTEM IN CASE OF LOW OUTPUT PICKUPS.)
FREQUENCY

FIG. 9 USEFUL RANGE LIMITS OF TYPICAL ACCELEROMETER PICKUP, INDICATING USUAL LIMITING FACTORS

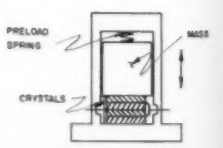

FIG. 10 PIEZOELECTRIC

Principle. Stack of piezoelectric crystals, electrically connected in parallel, forms sensing element and also constitutes elastic element in seismic system. Charge produced at terminals is proportional to stress induced in crystal stack by inertia force of mass, thus providing indication of case-mass movement. Damping, derived primarily from hysteresis in crystal material, is negligible. Principal piezoelectric materials used: barium titanate, Rochelle salt, ADP (ammonium dihydrogen phosphate), quartz.

Advantages: High output voltage (50 mv/g typical for low-range pickup working through short cable into high-input-impedance recording instrument); high natural frequency.

Disadvantages: Limited low-frequency response; output vol-

pickup at different input amplitudes, which may result in differences in response to various frequencies (frequency distortion) as well.

The presence and magnitude of this effect can be determined accurately only by more elaborate dynamic calibration procedures. These effects, which can be compensated for by the use of calibration curves, may still represent a problem in connection with measurement of transients, since the frequency of various components in the signature ordinarily will not be so determinable that the appropriate value of a calibration factor that varies with frequency can be applied individually.

Multiple Degrees of Freedom

In practice, the mass of the elastic element is not negligible and the system has some of the charactristics of a distributed-mass system with multiple degrees of freedom. In the case of an accelerometer the resulting effects become significant only at frequencies above the principal natural frequency, where the instrument response is badly distorted anyway. Hence they are of no importance within the operating range of the instrument. On the other hand, in velocity-displacement pickups (which, considered as an ideal system, have no theoretical upper frequency limit) these higher-mode resonances are usually the factor limiting the upper usable frequency range of the device.

Flexibility of the case and its mounting to the test specimen and of the mass results in a certain amount of motion in addition to the intended deformation of the elastic element. These extraneous deflections constitute part of the response of the system to the excitation but do not appear in the mass-case motion which is sensed. Therefore, the effective natural frequency and sensitivity of the instrument always tend to be lower than calculated. These effects, while undesirable because they reduce the usable range of the instrument, have little effect upon the mid-range accuracy of the instrument if dynamic calibration is properly carried out.

Effects of slippage or flexibility in pickup mounting cannot be accounted for by calibration of the pickup alone. The importance of rigid mounting in high-frequency work is evident from the minute displacements corresponding to a given level of acceleration: at 1,000 cps, a 10 per cent error in the measurement of 10 g will result from .00001 in. (¼ micron) relative motion between instrument and point of attachment.

Damping and Other Characteristics

Damping Properties. The damping element is assumed to be weightless and to provide a constant value of pure viscous (proportional to relative velocity) restraint. The actual effective mass of the actual damping element (fluid, for example) has the effect of further decreasing the effective natural frequency of the instrument, reducing frequency response range but not necessarily decreasing accuracy.

Since most instruments depend upon damping for maintenance of proper response characteristics through a considerable portion of their usable frequency range, damping value variation must be minimized. Doing this throughout the operating temperature range is difficult and the effect of large changes in damping upon accuracy will usually be unacceptably large unless compensated for or calibrated out, or minimized by operating the pickup at controlled temperature.

The presence of non-viscous damping, such as the dry or Coulomb friction introduced by the direct-writing element in some self-contained instruments, results in hysteresis and consequent loss of resolution which cannot be eliminated by calibration.

Sensing and Recording Characteristics. It is also assumed that the linearity, frequency response and resolution of the re-

Stathopoulos

Armstrong

Herewith the second and concluding installment of the penetrating analysis of shock and vibration pickup begun in the last (July) issue of EQ. The authors, John Armstrong and George Stathopoulos, write from long experience with naval ordnance. The former, chief of the NOL air and surface mechanical engineering department, has been at White Oak since 1943. The latter, who is staff consultant in the environmental simulation division, has been with the NOL since 1945.

For new readers of EQ who would like to have Part I of the Armstrong-Stathopoulos study, a limited number of copies of the July issue are available. Send 75c (postage is acceptable) to Environmental Quarterly, P. O. Box 2583, Grand Central Station, New York 17, N. Y.

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tage dependent upon minimized capacitance in cable and recording equipment; negligible damping; considerable transverse sensitivity; some materials are sensitive to temperature damage and/or effect upon output.

Variations: Crystals may be arranged to be sensitive to bending rather than compression; low-pass filters, damping-equivalent tuned corrective circuits, and impedance-matching (cathode followers) circuits may be used to overcome characteristic output difficulties.

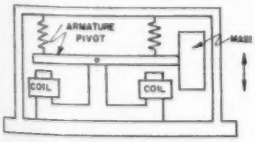

FIG. 11 VARIABLE RELUCTANCE

Principle: Seismic system consists of mass mounted on one end of spring-restrained armature lever of magnetic material. Under acceleration, rotation of armature changes gaps in magnetic circuits, increasing inductance of one coil and reducing inductance of coil in other circuit. Coils are active elements in a-c excited Wheatstone bridge which thus generates output voltage proportional to acceleration. Eddy current or viscous fluid damping is used.

Advantages: High output voltage; low output impedance; ideal for telemetry since accelerometer itself can be used as part of oscillator circuit; zero-frequency response.

Limitations: Requires exciting voltage at frequency at least ten times highest frequency to be resolved; requires balance circuit and demodulator.

Variations: One or four active legs of bridge may be included in instrument.

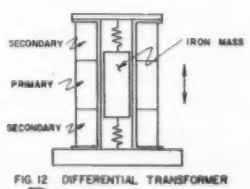

FIG. 12 DIFFERENTIAL TRANSFORMER

Principle: Magnetic core supported by springs within coil form wound with one primary and two secondary windings forms seismic system. Position of core determines relative coupling between primary and each of the secondary windings. Secondaries are connected in series opposition so that net output voltage is difference. When equilibrium output voltage is made zero by positioning core, relative motion of core within case results in output proportional to displacement. Damping is provided by immersion of seismic system in viscous fluid.

Advantages: High output voltage (50 to 200 mv/v); low output impedance; zero-frequency response; excellent linearity and very low transverse sensitivity; optimum damping.

Limitations: Sensitivity varies with exciting current frequency; requires exciting frequency at least ten times highest frequency to be resolved; requires demodulator.

Variations: Magnetic damping may be used to improve extreme-temperature performance; self-calibration may be provided by including additional coil.

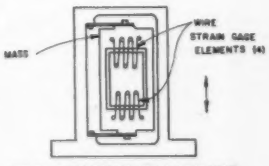

FIG. 13 WIRE RESISTANCE STRAIN GAGE

Principle: Four sets of fine wires, prestressed and electrically connected in Wheatstone bridge arrangement, support mass guided by flex plates and constitute spring in seismic system. Change in electrical resistance of wires is proportional to change in strain induced in wires by mass-case motion. Motion of mass is limited to elastic range of wires by rigid stops. Damping is provided by immersion of seismic system in viscous fluid.

Advantages: Excellent linearity and stability; low transverse sensitivity; low output impedance; zero-frequency sensitivity.

Limitations: Low output voltage (maximum of about 50 vm); optimum damping difficult to ob-

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tain in high-g pickups.

Variations: May use strain gages bonded to member constituting elastic element in seismic system; gas damping in diaphragm-coupled system may be used to extend high-frequency range, reduce effects of temperature on damping.

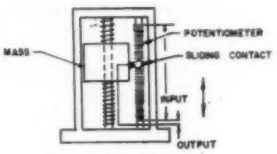


FIG. 14 POTENTIOMETER ACCELEROMETER

Principle: Resistance wire closely wound on mandrel is fixed to case. Wiper attached to seismic mass produces output voltage proportional to displacement of mass and thus to acceleration. Stops limit motion of mass to rated range; eddy current or viscous fluid damping is used.

Advantages: High output voltage; output impedance can be tailored to specific recording apparatus; zero-frequency sensitivity; simplicity.

Limitations: Accuracy limited by Coulomb friction of wiper; resolution limited by spacing of wire turns; acceleration limited by problem of maintaining wiper contact; wear limits use for steady-state measurements.

Variations: Unbalanced-range instruments can be made; units can be provided with taps for control or switching purposes.

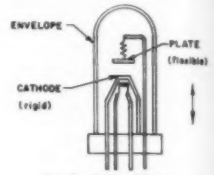


FIG 15 ELECTRONIC ACCELEROMETER

Principle: Flexibly-mounted plate in vacuum tube acts as seismic element; motion under acceleration is detected by change in plate circuit resistance. Cathode is supplied with heater power; plate circuit is connected in bridge to provide output voltage proportional to acceleration.

Advantages: High output voltage; light weight.

Limitations: Damping difficult to provide; considerable power and heat dissipation required.

Variations: May have double plate to provide two arms of bridge.

cording system are compatible with the limits of performance set by the seismic system's characteristics and that the motion-sensing system of the pickup is compatible in output characteristics (such as impedance) with the recording system and the transmission link between pickup and recorder. These factors often represent the governing limitations of the useful range of specific instruments. For example, modulated-carrier systems must operate at a frequency at least ten times greater than that of the highest frequency components of motion to be defined, which may introduce transmission or balancing problems. Overall system accuracy, of course, is essentially limited to that of the poorest element.

Types of Accelerometer

As the most important class of shock and vibration measuring device, accelerometer pickups are manufactured in considerable quantity and variety. While in general the capability of accurately responding to high-frequency components of motion is obtained at the expense of voltage sensitivity and the ability to record low values of acceleration, the nature of this and other interrelationships among desirable qualities varies radically among instruments operating upon different principles.

There is no single figure of merit which fully expresses the relative desirability of a particular type of pickup over a wide variety of applications, and no one type of instrument is clearly superior in all respects for most purposes. To provide a first indication of pickup usability, Fig. 8 summarizes acceleration, frequency and output voltage ranges for eight types of accelerometer. Ranges given are those covered by a family of pickups of the type indicated of varying sensitivity and full-scale limit, not necessarily by any one instrument.

Physical factors characteristically determining the practical limits of usability for a given accelerometer are shown in Fig. 9. The schematic principle of operation and outstanding advantages and limitations of common types of continuous-recording accelerometers are depicted and discussed in Fig. 10-15.

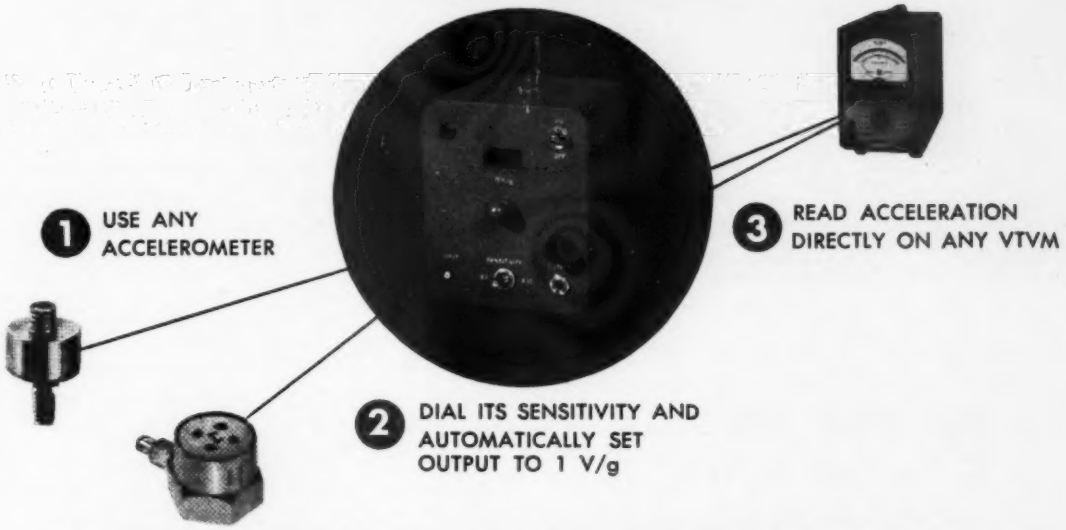
In these discussions, sensitivity is defined as high if the voltage output under normal use conditions is such that no special

(Continued on Page 50)

DIAL-A-GAIN

ACCELEROMETER SENSITIVITY STANDARDIZER

SIMPLIFIES ACCELERATION MEASUREMENTS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3 READ ACCELERATION DIRECTLY ON ANY VTVM

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- **VARIABLE GAIN**

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A lucid, well-illustrated manual on accelerometers by Endevco Corporation has proven to be one of the most popular booklets ever offered through the pages of Environmental Quarterly. This primer was condensed from the manual by the man who was in charge of its preparation.

Primer on Piezoelectric Accelerometers

by Warren D. Hancock

Chief of Technical Services
Endevco Corporation

VIBRATION and shock can be defined in terms of displacement, velocity or acceleration. Acceleration is the value most often desired because the destructive force is equal to mass times the acceleration. Acceleration, velocity and displacement measurements can be easily correlated only when the vibration being measured is a simple sinusoidal motion containing one frequency.

Unfortunately, vibration to be measured in practice almost always contains some harmonic distortion, even with sinusoidal laboratory shakers. For this reason, if acceleration data is required, true accelerometers should be used and correlation should not be attempted with velocity and displacement data without taking extreme care to isolate each specific vibratory frequency.

The ability of certain materials to generate a charge when subjected to a physical stress has been known for many years. Some of the common materials of this type are: Rochelle Salt, ADP, DKT, KDP, Quartz, Tourmaline, Barium Titanate, Lead Zirconate-Lead Titanate and Lead Metaniobate. These piezoelectric materials contain crystal domains which are oriented in the same direction, either by nature or by polarization during the manufacturing process. When stress is applied, the minute relative displacement of the crystal domains generates a charge. A full scale crystal deflection of 3 micro-inches may produce as much as 100 volts.

Piezoelectric accelerometers cover such wide frequencies as 2 cps to above 12KC and dynamic ranges as .001 to 30,000 gs. There are types that never employ damping, and so introduce no phase shift error. Case isolation, little affected by mounting, acoustic noise and other non-vibration environments, is also available.

The usefulness of piezoelectric materials depends on many factors, such as their internal resistance, charge gen-

erating ability and capacitance and the effect of temperature on these and other characteristics. Since in pure form they may not perform as required, materials have been developed with specific crystal elements for use in dynamic transducers.

Non-Vibration Environments

In this connection, non-vibration environments such as nuclear radiation and magnetic and RF fields may have an effect, and adequate isolation must be provided against ground-loops and stray signal pickup. A high intensity RF field may require special shielding of the accelerometer output cable and amplifier. Large doses of neutron and gamma radiation seem to cause a decrease in output and depolarization occurs gradually at higher radiation levels.

In flight or static testing, considerable vibration is induced by acoustical energy. It has been shown in numerous cases that random acoustical energy of 120 db can induce vibrations of the order of 50 gs or higher in structural members and it can be assumed that higher acoustic levels may increase the vibration levels, although not necessarily linearly.

It has also been shown that crystal accelerometers have, at the most, noise outputs equal to only a few gs at 150 db noise levels, so that if the usual high level vibrations are to be measured in acoustic fields, good signal to noise ratios and accuracies are obtainable. There are other cases, however, where low level evaluations on structures that are not subject to acoustic excitation must be made in high level acoustic fields. In these cases considerable attention must be paid to the acoustic response of the measuring system to assure good signal to noise levels and accuracies. The resonant frequency (fn) of the crystal accelerometers must be at least three times the highest acoustic frequency expected.

Mounting Accelerometers

Mounting is an important and sometimes overlooked technique in using accelerometers. When, for example, it is impractical to drill a hole in the test object, cement is useful, and there are several types available. For low temperatures cure point epoxies or dental cement may be used. Eastman #910 cement is very easy to use in normal temperature, non-humid environments. Non-hardening cements cannot be used because of decoupling. At least three kinds of double-backed tape are available: M M & M, Polyken and Tuck Tape. These tapes are useful in survey work at low g levels (below 10 gs and below 500 cps).

The mounting fixture is one of the most important aspects of vibration testing. Too often fixtures that were designed for testing at low frequencies are used for programs involving high frequencies. Many fixtures have resonant points which are below 2KC with Q's of 10 or more. This may result in severe over or under-testing, with resultant high component failure rates or over-design.

To properly design a fixture, the exact nature of its use must be known: frequency range, g level and, of course, the mechanical specifications of the test object. Individual fixtures should be designed for each component or instrument to be tested above 500 cps and 10 gs.

A fixture that introduces spurious response into the test obviously is not satisfactory, and as it is impossible to design the ideal fixture, it is mandatory that its exact characteristics be known in advance. Not only must the fixture be carefully designed, it must be tested and the vibration plotted at several points. The more complex the structure, the more points to plot.

Here are some major design considerations for a fixture:

1. The major resonant frequency must be well above or below the frequency test range.

2. The fixture should be as light as possible (magnesium alloy is preferred).

3. The static and dynamic center of gravity should be directly over the c. g. of the shaker and should be mounted as close to the head of the shaker as possible.

4. Cast fixtures are preferred, with machined assemblies and welded construction next in order. A welded fixture must be machined after welding.

5. Box or similar type construction which create a closed path to standing waves are to be avoided.

6. The test fixture must be rigid and as simple as possible. "T" & "U" shapes are useful when vibration is to be in one axis. "L" shapes are easily rotated 90° to the plane of vibration.

Shock Measurement

Since a shock pulse is made up of many simultaneous vibration frequencies, everything said about vibration applies to the use of piezoelectric accelerometers in shock measurement. In addition, shock testing imposes special problems not encountered in normal vibration work, including:

High g levels (from 100's to 10,000's of g's), very wide frequency response, transient response characteristics of instrumentation and repeatability of test conditions.

A shock pulse is usually a shaped acceleration time spectrum in the form of a half sinusoid, sawtooth triangular wave or square wave. In some cases the shock pulse is specifically shaped to contain a desired amount of energy in certain frequency bands. Most shock pulses contain essentially all frequencies from DC to well above 10KC.

For shock work the entire system must have a low frequency response 50 times greater than the period of the fundamental frequency for accuracy of 2%. Shown in Fig. 1 are the results of two instrumentation systems, one with

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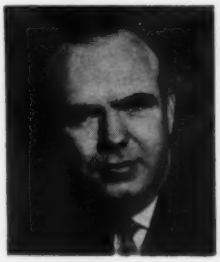

Hancock

Warren D. Hancock, sales manager for Endevco Corporation, Pasadena, Calif., is not only an author of considerable talent but a motion picture producer, too. His 16mm sound-color picture, "Vibration and Its Measurement," combined animation and live action in such a sparkling treatment of a technical subject that it won honorable mention in the first American Film Festival this year. Hancock became Endevco's sales manager two years ago. Before that he had founded Hancock Electronics Co., where he designed and manufactured closed circuit tv systems and related electronic products. He is a UCLA graduate of 1948.

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frequency response to 2 cps and the other with response 3 db down at 25 cps. Note that the instrumentation system without flat low frequency response completely distorts the acceleration time curve.

PULSE WIDTH OF 100 g HALF-SINE WAVE PULSE (No negative acceleration)	INDICATED ACCELEROMETER PEAK VALUE		INDICATED NEGATIVE ACCELEROMETER UNDERSHOOT	
	FREQUENCY RESPONSE		FREQUENCY RESPONSE	
	3db down at 25 cps	ENDEVCO 2 cps to 10 Kc	3db down at 25 cps	ENDEVCO 2 cps to 10 Kc
20 millisecond	0 g	96 g	Unknown	−6 g
11 millisecond	10 g	98 g	Unknown	−4 g
6 millisecond	51 g	99 g	−52 g	−2 g
2 millisecond	75 g	100 g	−40 g	0
1 millisecond	87 g	100 g	−26 g	0
500 microseconds	91 g	100 g	−18 g	0

Figure 1

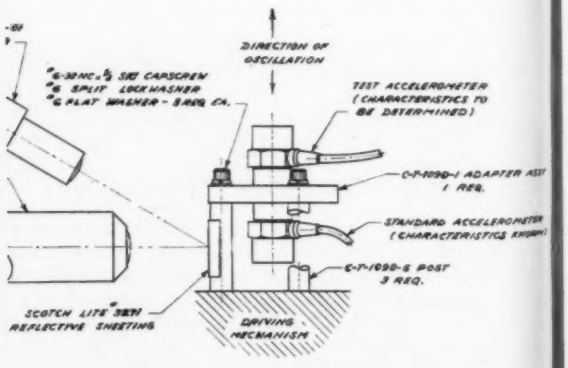
Filters are not recommended for shock work since they distort peak acceleration values and introduce phase shift which will change the shape of the acceleration time curve by shifting different parts of the spectrum by varying amounts. If the test specification calls out the use of a filter, it is strongly recommended that the unfiltered response from the transducer be monitored as well. The need for filters can in general be eliminated by choosing piezoelectric transducers with natural frequencies of 50 KC or higher.

Basic Sensitivity Measurement

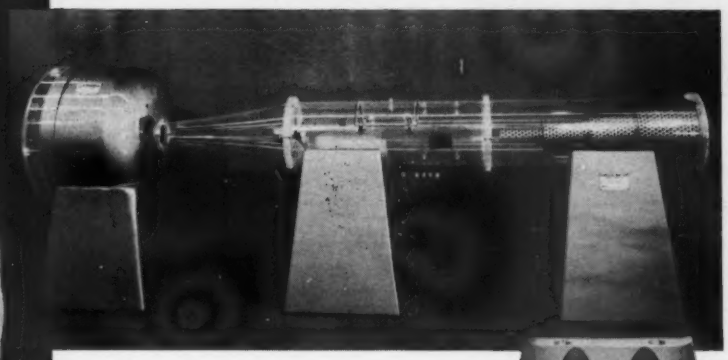
The calibration of a DC type accelerometer is relatively simple, while the calibration of a dynamic accelerometer is necessarily more complex. The most accurate method developed to date is based on optical calibration of displacement by means of a microscope or other suitable device. Optical calibration has the distinct advantage of being a fundamental measurement: it does not introduce the errors of another transducer system. The vibratory function must be a single frequency sine wave free of all distortions.

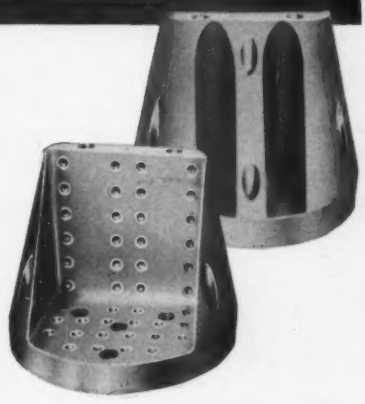
When any appreciable amount of material exists between the accelerometer being calibrated and the other measuring instrument, there is a increasing uncertainty that the two devices are going through the same motions at higher frequencies. This applies to signal coil generators which usually are mounted some distance down from the vibrating table surface on which the accelerometer is mounted.

(Continued on Page 52)


DIRECTION OF OSCILLATION
TEST ACCELEROMETER (CHARACTERISTICS TO BE DETERMINED)
C-7-1090-1 ADAPTER ASSY 1 REQ.
STANDARD ACCELEROMETER (CHARACTERISTICS KNOWN)
C-7-1090-5 POST 3 REQ.
SCOTCH LITE REFLECTIVE SHEETING
DRIVING MECHANISM

MOUNTING ASSEMBLY OF ENDEVCO TEST SHAKER





(left) **Shock Machine** SM-010, with shock pulses up to 1000 g's, meets rigid specifications of WS-107A-2 Environmental Test Requirements for ballistic missile components.

(above) **Acoustic Noise Generator** AG-012, producing up to 163 db of random noise, can be used singly or in systems with other speakers to meet specific testing requirements.

(right) **Environmental Test Fixture** (two views shown) is compact and versatile. Handles several specimens along three mutually perpendicular axes. Mounts on standard vibration exciters, centrifuges and shock machines.

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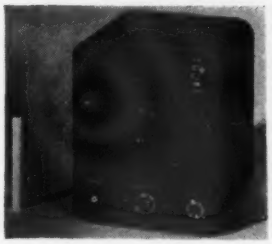
ACCELEROMETER SENSITIVITY STANDARDIZER by **Unholtz-Dickie Corporation** allows direct reading of acceleration on any VTVM by converting accelerometer sensivities to 1 volt/g. Called **Dial-A-Gain**, it includes a cathode follower input and a precision amplifier with a continuously variable logarithmic gain control dial, hand calibrated directly in accelerometer sensitivities. External cathode followers are eliminated.



Available with single or multiple-inputs.

For More Information Circle EQ RSC #1

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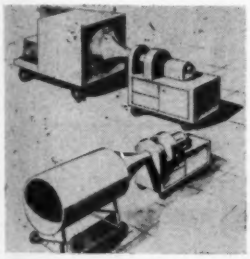

For More Information Circle EQ RSC #2

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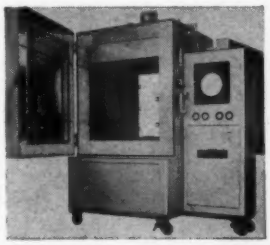
HIGH-LOW TEST CHAMBER, Model FB-30, by **Conrad, Inc.,** allows production line techniques by means of doors on opposite sides. Tests can be put in from one side and removed from the other. Thirty cf. Each door has a 2 sf viewing window. Features include Conrad's patented cascade system, recording controlling of temperature conditions, quick action door locks, and heavy duty industrial casters for mobility. Costs about one-third more than a single duty unit.



For More Information Circle EQ RSC #3

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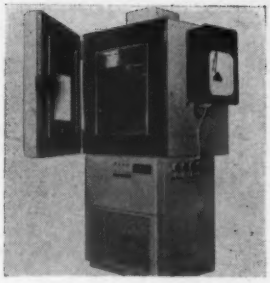
SHOCK AND VIBRATION ISOLATORS for temperatures up to 500° F. have been added to **MB Electronronics' Isomode** line. Consist of two load carrying springs mounted in opposed positions with built-in damper assembly to restrict resonant buildup. No external cooling needed. Meet MIL-E-5272A vibration and shock specs.

For More Information Circle EQ RSC #4

THREE-CUBIC-FOOT TEMP. CHAMBER with optional relative humidity has been added to **Tenney Engineering, Inc.'s** standard line. A 10 cf model was previously the smallest available with the humidity option. Standard features of the **Tenney-3**: —40°, —100° or —120° F. to +240° or +350° F; one hour from ambient to —100° F., 70 minutes from ambient to +350° F; patented cascade Freon 13 and 22 mechanical refrigeration. Options include CO_2 refrigeration, and relative humidity of 20% to 95% in the dry bulb range of 35° to 185° F., limited by a 35° F. dew point, 5% at 160° F.



For More Information Circle EQ RSC #5

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SINE WAVE VIBRATION SYSTEM, 70 pounds force, by **Ling-Altec Electronics, Inc.,** provides continous operation for testing small components and systems over 5 to 2,000 cps freq range. No impedance changing or manual power factor correction is needed. Couples a Model RA-250 power generator driving a Model 227 electro-dynamic shaker. The same generator will also drive an acoustic vibration system. Power generator components include Altee 260A amplifier. Model 227 wide-band shaker has a maximum output of 150 lbs-force. It has a dual magnetic field and high first resonance of about 9,000 cps bare table.

For More Information Circle EQ RSC #6

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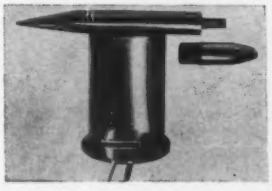
LINEAR ACCELEROMETER by **Genisco, Inc.,** provides an AC output voltage proportional to applied acceleration. Gas damped, it provides an essentially constant ratio over a very-wide temperature range. Supports allow a low spring constant on the sensitive axis, but rigid constraint on the non-sensitive axes. The pickoff is electrically similar to a rotary differential transformer. Features: output impedance below 500 ohms, high output power with low distortion and range of ±.5g to ±50g. with total accuracy better than ±2% at full scale. Operating temps are —60° to +160° F. Two inches in diameter, 2¾" long. Weight is less than 1 lb.

For More Information Circle EQ RSC #7

• • • •

SUPERSONIC, STRUT-MOUNTED TEMPERATURE PROBE by **Propulsion Development Laboratories, Inc.** takes high altitude readings. Resistance bulb and thermocouple sensing element are thermally balanced through an integral anti-icing element. Temp range —100° to 800° F., altitude range sea level to 150,000 ft., mach .20 to 3. Meets MIL-E-5272B (vibration) and MIL-B-7990A (resistance bulb) specs.



For More Information Circle EQ RSC #8

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LABORATORY TURRET, Model BL-4200, by **T & S Brass and Bronze Works, Inc.,** handles gas, air or vacuum service and is fitted with standardized and interchangeable heavy duty hose cock. Heavily chrome plated turret has a ⅜" IPS female inlet and is available with one, two (90° or 180°) three or four hose cocks. Also supplied without hose cocks and with ⅜" IPS female outlets.

For More Information Circle EQ RSC #9

ACOUSTIC VIBRATION SYSTEM by **Altec Lansing** provides high intensity sound equal to the shriek of the loudest jet and missile engines. Designed to reproduce frequency and amplitude conditions equal to actual flight, it consists of an aluminum double wall reverberation chamber with 30-cubic foot capacity and 16 low freq and 16 high freq loudspeakers. Eight 260-watt Altec power amplifiers covering the lows and highs are frequency controlled by two band pass filters slaved to a pair of pre-amps which

feed a third pre-amp which mixes the outputs and drives the speakers with up to 147 db of white noise.

For More Information Circle EQ RSC #10

• • • •

ULTRA-TEMP OVENS by **Blue M Electric Co.** have a temperature range from 150° F. to 1200° F. with a control point of ± 2° F. Automatic control proportions external thermocuple resistance and shifts pointer control closer to point of actuation. Ovens guaranteed to meet Air Force MIL-H-6088A. Units come in four standard sizes from 1 to 11 cf.

For More Information Circle EQ RSC #11

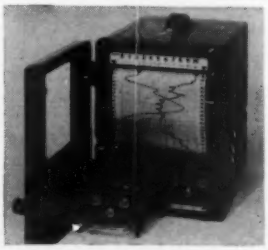
• • • •

VACUUM OVEN WITH RECIRCULATING BLOWER by **Grieve-Hendry Co., Inc.** provides vacuum to 29.5 in. mercury by rotary vane type cooled pump with forced feed lubrication. Temperatures to 500°F. input of 45 kw for fast heatup is automatically reduced to 15 kw after heaters have reached maximum surface temp. Doors cn each end of the 48 x 72-in. work chamber facilitate straight line processing. Recirculating blower increases speed in work load heating before and during vacuum pumping.

For More Information Circle EQ RSC #12

• • • •

TWO CHANNEL POTENTIOMETER RECORDER by **Varian Associates,** Instrument division has two standard and four optional speeds, weighs 35 pounds and is available i n either portable or panel mount versions. Both pens of the **Varian G-22** traverse full width of 5-in. chart. Range is adjustable from 0-9 mv to 0-100 mv. Chart speed options range from 1/8 in/hr to 8 in/min. Accessories include alarm con-



tacts, retransmitting potentiometers and event markers.

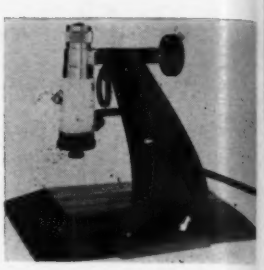
For More Information Circle EQ RSC #13

• • •

HIGH-SPEED 16mm PULSE CAMERA, Model 360, by **Chadwick-Helmuth Co.** can handle pulsing rates up to 18 frames per sec, with the 50 ft. film magazine providing two minutes of vibration testing at this rate. Designed for use with strobe lights it can produce with accessory equipment slow-motion movies of vibration or other cyclic tests at speeds up to 10 kc.

For More Information Circle EQ RSC #14

PLASMA GENERATOR by **Avco Research and Advanced Development Division** said to provide a relatively inexpensive source of temperatures ranging from 2,500° to above 12,000° F. Measures only 2¼ x 9 in. and weighs 3½ lbs. Can be fired into a vacuum or pressure chamber without major modification. The plasma jet operates from standard welding generator using commercial bottled gas, such as argon, nitrogen or helium, and tap water is used for cooling.

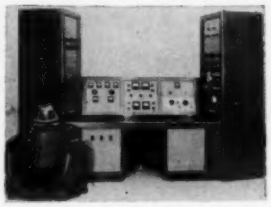


Standard nozzle is .375 in. inside diameter; others from .25 to .5 in. available.

For More Information Circle EQ RSC #15

• • •

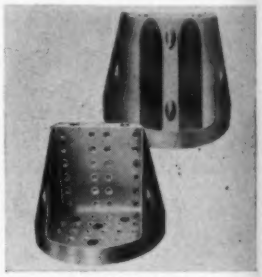
RANDOM WAVE VIBRATION TEST SYSTEM for automatic programming, **Model CP-5/6R** by **Ling-Altec Electronics, Inc.,** repeats standardized random noise and sine wave tests at the push of a button over 5-10,000 cps freq range. No impedance changing or manual power factor correction is required. Said to be the first completely integrated amplifier-console for random operation, meeting all government and industry vibration test specs. Console measures 4 x 10 ft., and houses power generator, field and degaussing supply cycling oscillator, servo system and controls. Provides a peak random force of 2500 lbs., and sine wave vector force of 1500 lbs. with a Ling Model A-174 shaker.



For More Information Circle EQ RSC #16

• • •

MULTI-PURPOSE FIXTURE essentially resonant-free below 2,000 cycles during normal use in vibration, shock and acceleration tests by **Avco Research and Advanced Development Division.** Can handle specimens in three mutually perpendicular axes simultaneously. Transmissibility factor said not to exceed 1.10 up to 2,000 cps. Made of cast magnesium. Available in sizes for 1,500 and 5,000 g-pound exciters, smaller unit has dimensional capacity of 6 x 6 x 4½ in. up to 6 lbs., larger can handle 12 x 12 x 9½ in. to 25 lbs.

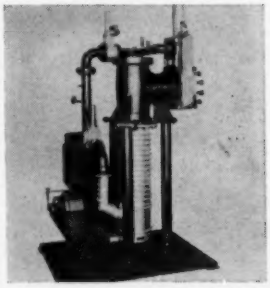


weight. Similar fixtures using beryllium have also been developed for more demanding test programs.

For More Information Circle EQ RSC #17

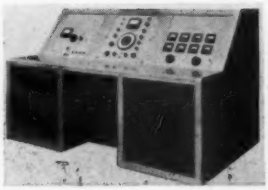
• • •

HIGH VACUUM PUMPING SYSTEMS by **General Vacuum Corp.** includes caster-mounted portable units of 2, 4 and 6-in., and skid-mounted assemblies, 10, 16 and 32-in. The **Series 1400** line includes manifolding, valves, air and water piping, wiring and controls ready for coupling. Diffusion pumps with mechanically refrigerated or liquid nitrogen cooled traps. Mechanical boosters are added for rapid pump-down where outgassing is heavy at intermediate pressures. Pictured is **Type 1410,** a 10-in. diffusion system.



For More Information Circle EQ RSC #18

THREE-KW AMPLIFIER, Model T-151 by **MB Electronics** has less than 5% distortion and noise & hum level 40 db below signal at full output. Features include a automatic power factor corrector and a 5-5000 cps wide band cycling oscillator with automatic acceleration and displacement control. Various exciters of freq



ranges 5-3000 cps handle up to 2200 force-lbs. vector.

For More Information Circle EQ RSC #19

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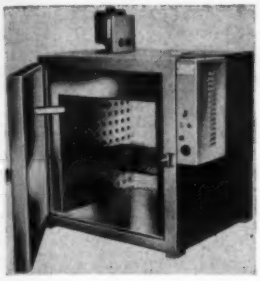
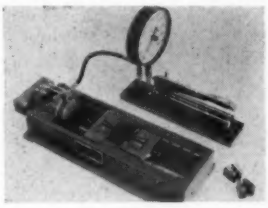


BATCH TYPE OVENS by **Blue M Electric Co.** have a in five models with temp ranges of 100°-300° F. and 100°-500° F., and supply 8 cf of heated volume. Triple wall, Fiberglas insulation, all welded steel constructions external thermocouple teriors and grey enameled exteriors. Outside measurements: 37" W x 32" D x 44" H. Available in 115v, single phase; 230v single or 3ph; and 440v 3ph.

For More Information Circle EQ RSC #20

* * *

PORTABLE TENSILE TESTERS, by **Steel City Testing Machines, Inc.,** can perform standard tensile tests mounted horizontally and either tensile or compression tests mounted vertically. Available in two general sizes: **PT-20** units with capacities from 5,000 to 20,000 pounds, and **PT-40,** 20,000 to 40,000 lbs.



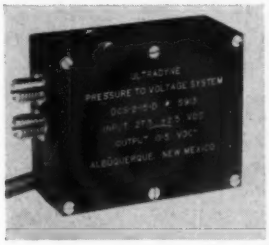
For More Information Circle EQ RSC #21

PRESSURE-VACUUM CONTROLS, Type J27 (uncalibrated) and **Type H27** (calibrated) by **United Electric Controls Co.** have a switch differential of ¾ ± 1" w.c. and up. Range limits on the several models are within 30" hg, vac and 15PSI. Stainless steel or beryllium bellows are offered. Switches are single pole, suitable for working temperatures up to 180°F. Available as normally open, normally closed, or double throw, with no neutral. Rated 3 amp. 115/230v. AC.

For More Information Circle EQ RSC #22

* * *

UNREGULATED PRESSURE TO VOLTAGE SYSTEM, Model DCS-2, by **Ultradyne, Inc.,** combines Model S-30 pressure transducer with stable transistorized electronic circuitry containing mostly passive elements. Operates from 28-volt DC aircraft and missile systems and has a signal output of 0-5 or ± 2½ volts DC over the rated pressure range. Only moving part is the stiff metal diaphragm, for resistance to shock and vibration and virtual elimination of acoustic vibration fatigue. Transistorized multivibrator works into a passive circuit containing a temperature-stable phase-sensitive demodulator using matched silicon diodes.



For More Information Circle EQ RSC #23

400,000 G POUNDS
ACCELERATION TESTING with RUCKER CENTRIFUGES

Large Rucker Centrifuge Acceleration Test Machines provide accurate environmental testing of components, instruments and complete assemblies for military facilities, missile manufacturers, allied industries participating in the rocket and missile development program.

RUCKER FEATURES

- Proven design offers greatest range of simulated acceleration and combined environmental tests
- Safety factor of 5
- Counter-rotating specimen platform
- Test chambers for temperature, humidity, altitude and vibration
- Electrical slip rings
- Complete interlocking system for fail-safe operation
- Maximum accuracy through high inertia design and precision control system
- Hydraulic-pneumatic rotary joints
- Closed circuit TV
- Wave guides for all applications

Ideally suited for exacting laboratory testing or production test procedures, Large Rucker Centrifuges are available in six standard models accommodating specimen weights from 300 to 9,000 pounds and with centrifugal capacities to 150 G. Larger models custom-designed to meet special needs.

Small Rucker Centrifuges also available.

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ATTENTION: Openings now for Qualified Engineers—for Design and Sales

The Threshold of Knowledge

(Continued from Page 14)

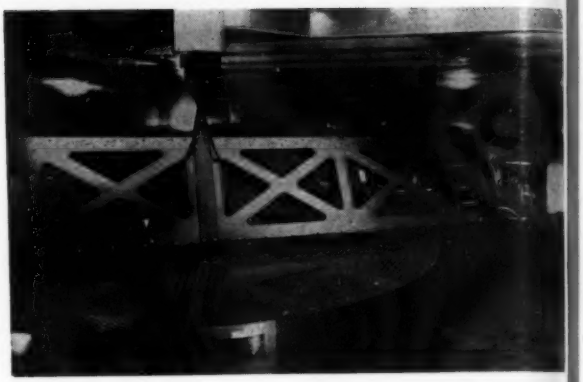
There are two basic applications in G force testing. One, perhaps the most common, is proof testing: Subjecting an article or component to a G force environment. Here accuracy is of very little importance, the object being to establish that the device will function properly while being subjected to forces in excess of those expected in actual use. Crude and simple devices suffice.

Calibration Testing

At the other extreme is the second application for acceleration testing, that of calibration. Guidance systems designed to take over control of a missile the instant it leaves its launching pad, and thereafter detect, measure, integrate and use information relative to accelerations in any quadrant of a sphere, must necessarily be extremely precise and exacting.

Obviously, these systems require the extreme in testing equipment accuracy. Variations in rotational speed, presence of vibration, the tendency to increase or decrease in speed in a single revolution (commonly referred to as "wow"), or drift due to a minute error in speed setting or incapability of a selected speed setting to remain fixed, all contribute to error. In fact, it has been proved that a ¾-inch diameter conduit secured and standing vertically against the wall in a pit 25 feet in diameter can produce sufficient aerodynamic disturbance to cause a pip each time a table weighing several hundred pounds whirls past.

In the Garden City, N. Y., plant of American Bosch Arma Corp. and the AC Spark Plug Division of General Motors in Milwaukee are highly advanced machines possessing an overall performance accuracy of one part in 100,000. These machines required numerous total departures from accepted practice. For example, since the maximum allowable variation in radius of gyration at the mounting platform was two-ten-thousandths of an inch, a conical bearing of a particular design had to be devised. No commercial precision bearing could hold that tolerance.



PRECISION END OF CENTRIFUGE ARM of the G-460, which is so critically balanced that it can be set in motion by pushing it with the pinky, can test to 10 gs. The other end can handle up to 300 lbs. at 25 gs. Arma uses the centrifuge to test its new Titan guidance system accelerometer, which can measure accelerations as minute as .000005 g.

The basic drive system had to be constructed around a crystal-controlled frequency source with the means of converting the crystal output to three-phase alternating current, variable in frequency from .3 cycles per sec. to 7 cycles per sec.

Also necessary were means of compensating for strain elongation due to centrifugal force, variation in boom length due to temperature changes, static precision radius measurement and dynamic precision radius measurement to verify under operating conditions that no variation in radius had crept in. Means of static and dynamic balancing via remote control had to be included to assure a maximum reduction of strain and imbalance which, if present, would result in the introduction of error.

TWENTY-ONE-FOOT DIAMETER SILO housing the Genisco G-460 centrifuge at American Bosch Arma Corp.'s Garden City, N. Y., lab has a ¾-inch steel wall, seven feet high, a matching ⅜-inch aluminum liner and is round to within 1/16th of an inch. The space between outer and inner walls permits air flow to maintain constant temperature within, to keep the length of the 100-inch centrifuge arm to 100-millionths of an inch.

Combined Environments

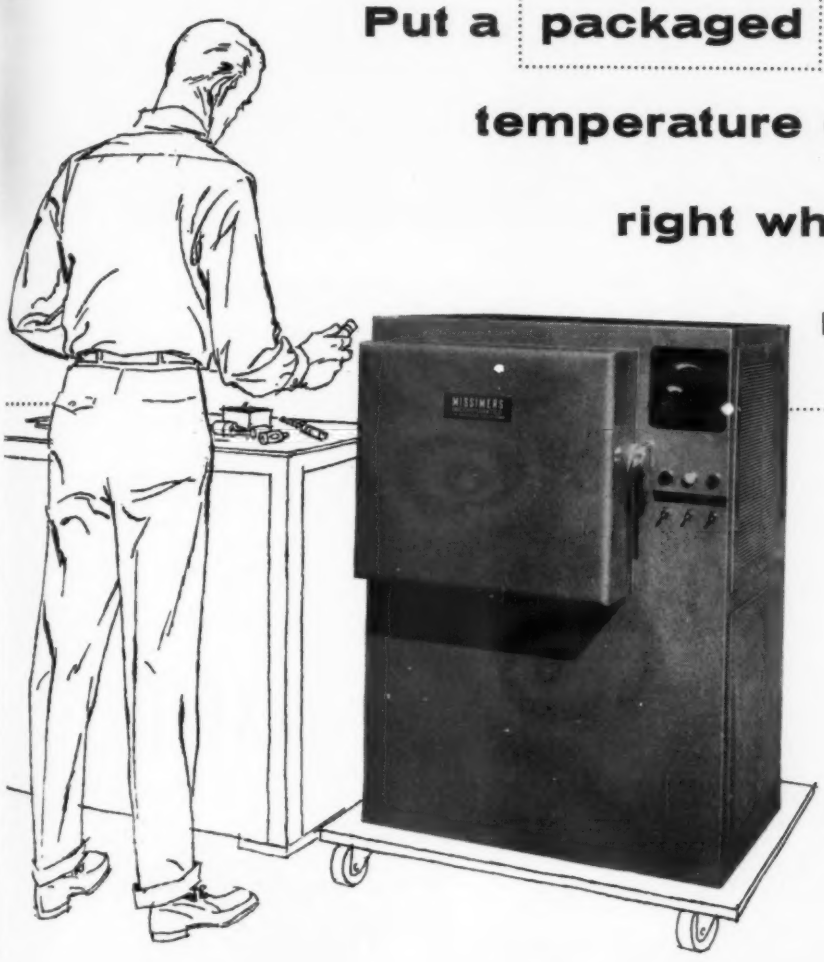
Any airborne or space-spanning device meets a variety of transient, and in some cases, constant environmental conditions. The means of enduring them must be evolved or disaster will inevitably follow, particularly during transitional periods from the at-rest to terminal velocity, or from atmosphere to space, or from space to atmosphere, or in a manuever or a turn in any environment.

Under these conditions the activation of the propulsion system, the deviation from a natural course induced by the acceleration to a given velocity, or the movement through more or less atmospheric density all produce acceleration and vibration forces. Aerodynamic forces when atmosphere is present cause flutter, pitch and yaw tendencies. Sonic vibration and many other forces must be reckoned with.

Sojourns in space bring problems of corona in electrical systems, radiation from the newly discovered Van Allen belts and the ever present high velocity radiation from the sun and outer space. Micro meteorite particles zooming

(Continued on Page 48)

Put a packaged temperature chamber right where you need it...



THIS ECONOMICAL MISSIMERS CHAMBER MEETS MIL-SPEC ACCURACIES WITH PLUG-IN SIMPLICITY

Quickly set up almost anywhere, this new unit is designed to fill the need in many testing laboratories and company facilities for an accurate, yet economical temperature chamber. It can handle overflow work from larger chambers, run qualification and reliability tests on small products or components, and is ideal for production processing and temperature stabilization work.

A hermetically-sealed cascade refrigeration system provides temperatures to −100°F, and a special heating unit to 350°F. Temperatures are controlled to ±3°F over the full range.

The one cubic foot working space has a full opening door. Forced air circulation provides uniform temperatures within the chamber.

As a standard model, this chamber is priced to be practical for almost anyone... will test to Mil-Specs... and is guaranteed for a full year.

Write for specifications and prices on Model FT1-100x350, or for information on any of Missimers full line of environmental chambers.

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Western Sales Representative: Pacific Scientific Company

The Threshold of Knowledge

(Continued from Page 46)

about in outer space, unrestricted in their terrible velocities, could in sufficient densities destroy anything that encountered them unless there was some way to absorb, deflect or detect and avoid them.

Therefore centrifuges which combine as many of these conditions as practical must be provided. Machines have been produced which do combine low or elevated temperatures, vibration and near zero atmospheric pressure. Other conditions of sand, dust, salt spray, fungus and shock are being discussed and present few problems. Radiation will inevitably be required along with vibration and acceleration under space conditions of essentially zero atmospheric pressure.

Other applications of step function G tables, spatial orientation tables which hold a fixed relationship with a point in space except for earth's rotation, are also in demand. These, in some cases, must be combined with devices to cancel out earth rotation.

Other Testing Devices

The degree of accuracy required in resolving the problems of space navigation were considered totally unrealistic just a few years ago. The work of Dr. Draper and his laboratory personnel at M.I.T. have provided the foundation for bold steps in the direction of heretofore untold accuracies. The floated gyro with its fantastically low drift rate and the inertial accelerometer with its capability of detecting a .000005 part of a G unit exemplify this progress.

Such pieces of guidance equipment, once built, must be proven; theory of operation is not enough. Consequently, testing equipment capable of providing input characteristics of precisely known quantities or rates to a device under test, with means of observing the device's ability to detect and properly interpret the phenomena presented, becomes a prerequisite of continued development. To this end, we have rate-of-turn tables and auxiliary equipment for threshold measurement and attitude positioning. Rates of turn devoid of measurable variations as low as one revolution in 46 days are now easily available—and this is only the beginning of the application of slow motion phenomena. It is possible to reduce that value by a factor of 100, 1,000 or 1,000,000 as you will; thus, one revolution without pause in 126,000 years is available if anyone cares to wait around for the device to revolve once.

Readouts to accuracies of one second of arc are now required and available; fractioning that value is next in line and being worked upon. Endless other devices are required in the field and in the missile to exercise vital components in the static prefiring state to be certain they will function as prescribed in the dynamic state of flight.

The environmental equipment and ground support field has a brilliant and promising future for those who face its challenges cheerfully, logically, and intelligently. The ships in which Columbus crossed the unexplored ocean in 1492 were highly advanced in the state of the shipping art with more than 4000 years of development behind them. Spacecraft is only two years old.

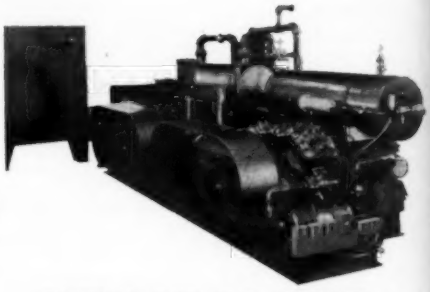
DEPENDABLE ENVIRONMENTAL TEST UNITS

TEMPERATURE • HUMIDITY • ALTITUDE • EXPLOSION
FUNGUS • SAND and DUST • CLOUD and POUR

Atlas Engineering Corp. represents over 50 years of aggregate experience in the environmental field. Proven engineering design coupled with constant research and improvement make it possible for Atlas to provide "The Newest and Best For Helping You Test." Write for Bulletin 957 describing standard test chambers.

Atlas will design and manufacture upon request special test facilities such as walk-in altitude, temperature and humidity rooms, liquid baths, etc.

For service, parts, or any information regarding Bowser Environmental Chambers contact Atlas—(Authorized service Rep.)



SPECIAL 100 H.P. CHILLER
DESIGNED TO HANDLE
90 G.P.M. OF METHYLENE
CHLORIDE DISSIPATING
60 KW at —60°F.

Atlas ENGINEERING CORP.
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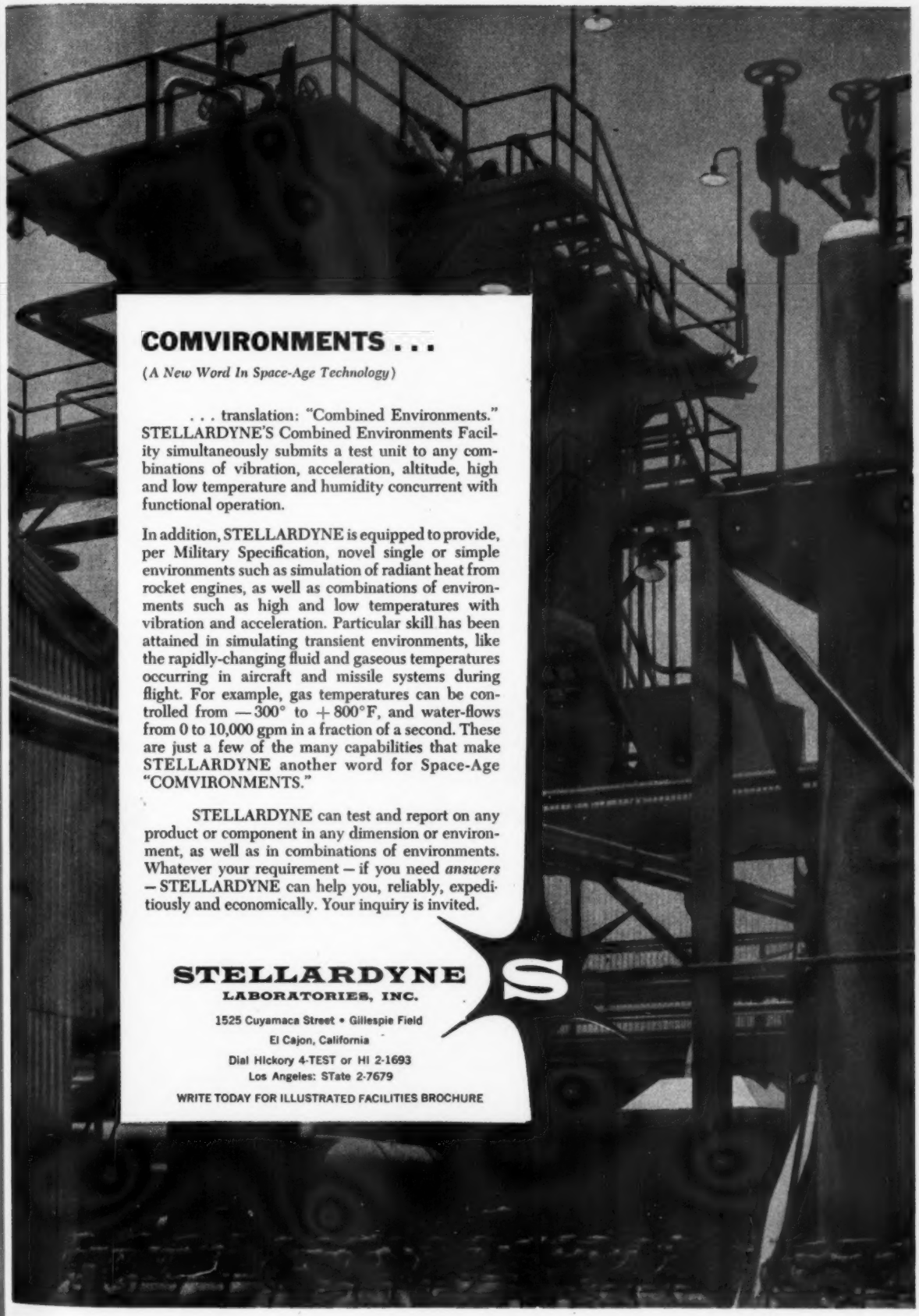

COMVIRONMENTS . . .

(A New Word In Space-Age Technology)

. . . translation: "Combined Environments." STELLARDYNE'S Combined Environments Facility simultaneously submits a test unit to any combinations of vibration, acceleration, altitude, high and low temperature and humidity concurrent with functional operation.

In addition, STELLARDYNE is equipped to provide, per Military Specification, novel single or simple environments such as simulation of radiant heat from rocket engines, as well as combinations of environments such as high and low temperatures with vibration and acceleration. Particular skill has been attained in simulating transient environments, like the rapidly-changing fluid and gaseous temperatures occurring in aircraft and missile systems during flight. For example, gas temperatures can be controlled from —300° to +800°F, and water-flows from 0 to 10,000 gpm in a fraction of a second. These are just a few of the many capabilities that make STELLARDYNE another word for Space-Age "COMVIRONMENTS."

STELLARDYNE can test and report on any product or component in any dimension or environment, as well as in combinations of environments. Whatever your requirement — if you need *answers* — STELLARDYNE can help you, reliably, expeditiously and economically. Your inquiry is invited.

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WRITE TODAY FOR ILLUSTRATED FACILITIES BROCHURE

Practical vs. the Ideal

(Continued from Page 36)

amplification is necessary in driving oscillograph units directly. Output impedance is described as high if impedance-matching (e.g., cathode follower) circuits are necessary if the signal is to be transmitted satisfactorily by cable. If the output impedance is characterized as low, such refinements as the use of co-axial, low-noise cable are required only for unusually precise measurements under adverse conditions of cable movement, electrical background noise and so forth.

Velocity Pickups. The characteristic frequency vs. velocity, displacement (peak-to-peak), and acceleration plot for a seismic velocity or displacement pickup is given in Fig. 16, with notes as to the typical sources of the limitations represented by the sides of the polygon. The principal type of instrument in this field is the electrodynamic velocity pickup, shown in Fig. 17.

Any seismic instrument whose case-mass motion-sensing element is responsive to displacement and adaptable to fairly low

(Continued on Page 52)

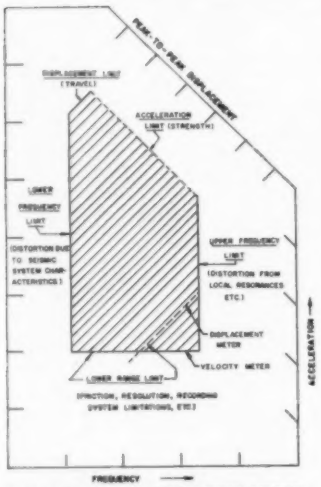

FIG. 16 USEFUL RANGE LIMITS FOR TYPICAL VELOCITY DISPLACEMENT METER PICKUPS INDICATING USUAL LIMITING FACTORS

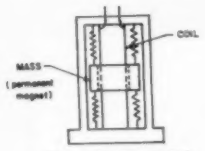

FIG. 17 VELOCITY PICKUP

Principle: Coil attached to instrument case is surrounded by permanent magnet supported on springs and acting as seismic mass in system. Voltage generated in coil as mass moves is proportional to their relative velocity. Eddy current (shorted coil) or viscous fluid damping provided for steady-state measurements; damping usually omitted for transient (shock) motion measurements.

Advantages: Self-generating; high output voltage (100 mv/in/sec is typical value); low transverse sensitivity.

Limitations: Massive unit for low frequency measurements because of travel required; somewhat restricted frequency range.

Variations: Magnet may be stationary element; short coil may be used in uniform, long magnetic field; magnet may be electrically energized.

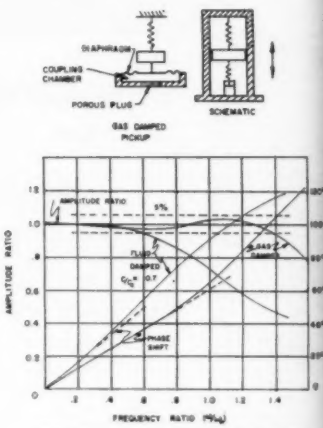

FIG. 18 TWO-DEGREE-OF-FREEDOM (GAS DAMPED) PICKUP (AFTER STATHAM)

HARRIS 2-CHAMBER UNIT GIVES DOUBLE TEST CAPACITY— HIGH OR LOW TEMPERATURE OR BOTH

Harris ingenuity, traditional since 1934, is exemplified in this double chamber environmental testing unit. The two chambers are completely separate and independently controlled, though chilled by a single refrigeration machine. Both provide complete temperature range from —125° F. to +250° F. Both may be operated simultaneously at either temperature extreme, or one may be set for low temperature and the other for high temperature testing. This exceptional versatility at least doubles the unit's capacity since two separate tests may be run at the same time. In use by several major electronic manufacturers, it has proved dependable, effective, and highly economical for production testing.

SPECIFICATIONS: **Outside dimensions — 74" long x 36" deep x 76" high. Net free working area in each chamber — 24" x 24" x 24" (8 cu. ft.). Temperature range: —125° F. to +250° F.**

Harris Model 2-8EL-AU2 2-chamber hi-lo temperature testing unit

HARRIS REFRIGERATION CO.

312 RIVER ST.
CAMBRIDGE 39, MASS.

Environmental testing equipment for every requirement, standard or custom models. Write for our advice. There's no obligation.

Beach-Russ VACUUM PUMPS

get your equipment to higher altitude conditions FASTER

The correct type and size vacuum pump for your specific needs is available from the Beach-Russ line of more than 30 single- and two-stage models. Our experienced engineering department extends an offer of technical help in your chamber development program.

Beach-Russ
COMPANY
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NEW YORK 17, N. Y.

Practical vs. the Ideal

(Continued from Page 50)

travel may be designed and used as a displacement pickup. Principles discussed under accelerometers which are usable include the differential transformer and potentiometer.

Multi-Degree-of-Freedom Instruments

The single-degree-of-freedom seismic system has generally been used as the basis for pickup design for shock and vibration measurement. It minimizes the number of design factors to be controlled in producing an instrument of predictable characteristics and its properties are reasonably well suited to the task.

Use of a more complex system such as is shown schematically in Fig. 18 allows additional latitude in adjusting system constants to obtain nearly unity amplitude ratio in an accelerometer up past the natural frequency. The theoretical response shown approximately doubles the frequency range throughout which ± 5 per cent accuracy is maintained as compared to a single-degree-of-freedom system.

Such multi-element systems, long used in acoustic transducers where response is required over a far wider frequency range but where accuracy of a lower order is acceptable, are finding their way into the shock and vibration measurement field as increased demands for performance warrant the effort required to make the more sophisticated systems accurate and practical.

ERRATA

In the first article of this two-part series, Equation 9 was incorrectly reproduced. The correct form follows:

$$\frac{\omega_n^2 Y}{\omega^2 X} = \frac{1}{\left[\left(1-\frac{\omega^2}{\omega_n^2}\right)^2 + 4\left(\frac{c\omega}{c_c\omega_n}\right)\right]^{1/2}}$$

In the same article, in the second paragraph of the section under "Transient Response" the expression for equivalent frequency should have been shown as π/T.

Piezoelectric Accelerometers

(Continued from Page 40)

In this case correlation cannot be expected beyond 1000 cps, and often 500 cps is the top limit.

At low frequencies up to several hundred cycles, the sensitivity of an accelerometer can be determined very accurately on a vibration generator by measuring the frequency of pure sinusoidal vibration and using a microscope to measure the amplitude of vibration. Accurate g levels cannot be computed above 200 cps because displacements for reasonable g values become so small as to be unresolvable by ordinary microscope techniques.

Interferometers provide, theoretically at least, very high resolution of small displacements, but in practice they are extremely complex to use and maintain. The National Bureau of Standards has refined interferometer technique to the point where it estimates the accuracy of the calibration to be 1-1/2% over a limited frequency range. High frequency calibration can be accomplished by the "reciprocity" technique. Estimated accuracy of this technique is 2% at frequencies below 1000 cps to 6% at 10 KC. Independent experimental checks confirm this figure. However, the reciprocity technique of calibration is a long and tedious one and it is impractical to calibrate each accelerometer in this manner.

The comparison method of frequency calibration over a broad range is probably the easiest to employ. It means simply comparing an unknown with a previously calibrated accelerometer. This method is capable of producing results to within ± 1%.

AR

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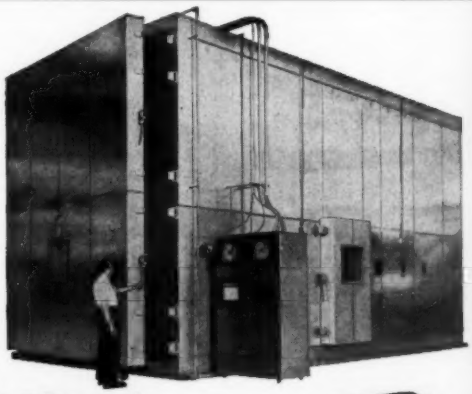
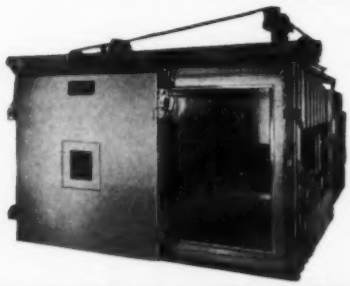


◀ Altitude, Temperature Humidity walk-in chamber 10′ high x 8′ wide x 12′ deep interior with push-button door controls inside and out.



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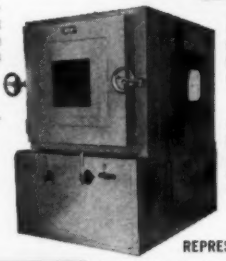

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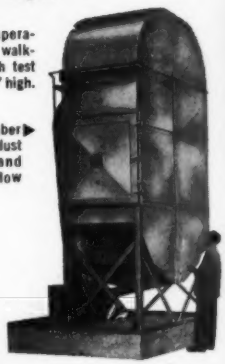

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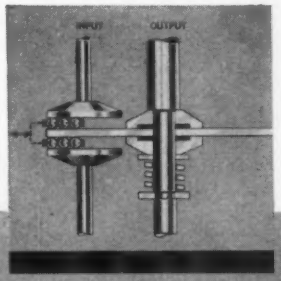

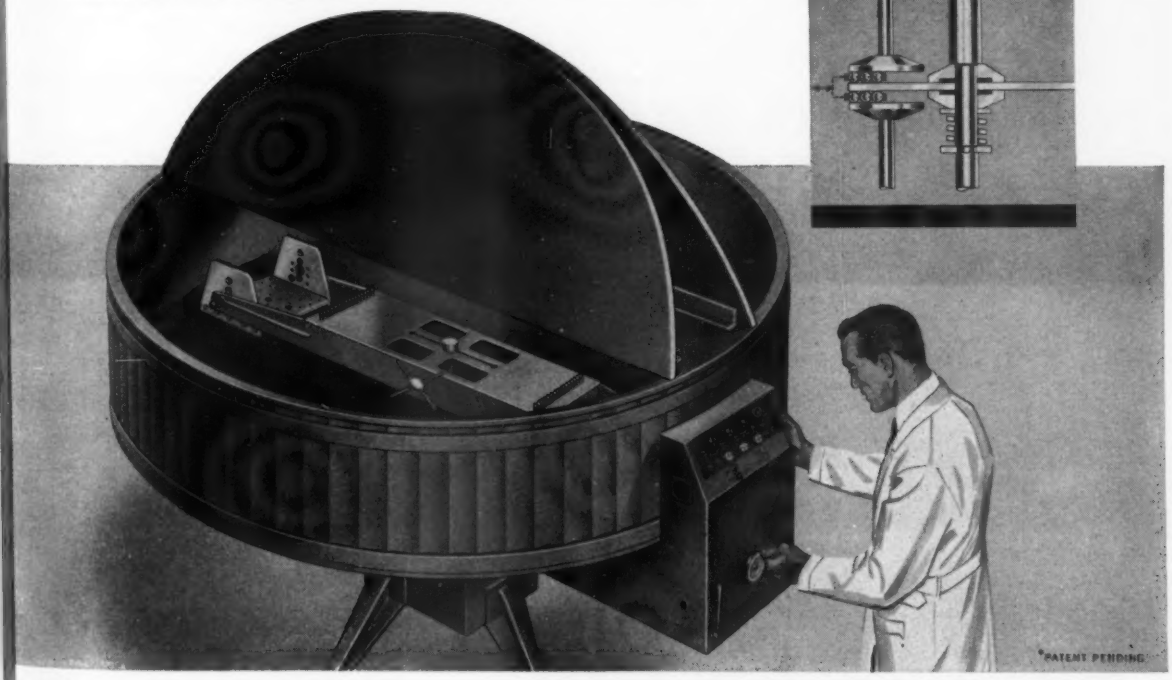

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Model No.	Diameter	Test Object Weight	Capacity G-pounds	RPM Max.	G-Range Max.	Test Object Dimensions
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A-1020	60" arm	100 lbs. dead weight	10,000	600	.1 to 250 g's	12" cube
A-1030	96" arm	100 lbs. dead weight	10,000	355	.1 to 150 g's	18" cube

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The Plus and Minus of CO_2

(*Continued from Page* 22)

units which can be easily shifted to any area. Incidentally, large carbon dioxide storage receivers, in 4, 6, 12, 25, 40, and 60-ton standard sizes, are available for either or both of these supply systems.

With CO_2, it is a simple matter to convert high temperature ovens to low temperature test chambers. Even a plywood box can serve as a low temperature chamber for a temporary requirement.

SOLID, LIQUID OR GAS? SOME TIPS ON CO_2 USES

by John P. Antolak
Director of Carbon Dioxide Technical Sales
Liquid Carbonic Division, General Dynamics Corp.

Carbon dioxide is avaliable as a solid, liquid and gas. The gas is not recommended for environmental work because of its low refrigeration capacity from the sensible heat during expansion.

At atmospheric pressure, solid CO_2—dry ice—is at a temperature of —109.6° F. and has a latent heat of 246 BTU/lb. In small test chambers, crushed dry ice is placed in a wire or expanded metal basket and air is blown across it. Temperatures approaching that of the dry ice can be obtained. Control equipment and the supply of refrigeration and refrigerant are fairly simple and inexpensive.

Where testing is sporadic, or where a few, widely separated small cabinets are used, dry ice may be the most efficient and practical form of carbon dioxide. But for greater efficiency and refrigeration flexibility where testing is frequent, for installations of several chambers and for chambers requiring large refrigeration capacity at peak demand, low pressure liquid carbon dioxide should be used.

Low pressure liquid CO_2 is stored in insulated, coded, unfired pressure vessels at approximately 300 PSIG and 0° F. The storage vessel is generally owned and serviced by the carbon dioxide supplier and is made available at no charge as part of a service contract. The storage unit is self-contained with safety devices, control instruments, refrigeration compressor, level indicator and related equipment. It is necessary only to run electric power lines to it.

Low pressure liquid CO_2 is piped through insulated lines, but heat pick-up in extended pipe lines may necessitate installing a recirculating pump to assure maximum efficiency at the point of use. Low pressure liquid carbon dioxide has a latent heat of approximately 115 BTU/lb. It is necessary only to meter the correct amount into a chamber to get any desired refrigeration capacity.

Direct injection of low pressure liquid CO_2 is extremely efficient, but when testing fuels and hydraulic oils, when making human factor tests, or when personnel have to enter a test chamber, direct injection may not be practical. Under such conditions, either liquid or solid CO_2 may be used to cool a solvent which is circulated through coils in the chamber. Control is easy with liquid CO_2. Acetone, methanol and trichloroethylene are the most commonly used solvents.

For extremely small chambers, remotely located chambers or chambers used only occasionally, liquid CO_2 is available in cylinders. This liquid has a latent heat of approximately 70 BTU/lb. at room temperature.

Actual refrigeration capacity, when using high or low pressure liquid CO_2, is determined by the size of the nozzle or orifice at the point of discharge. It is customary to size the orifice to deliver approximately 10 per cent more than the peak refrigeration demand and to use a control valve to stop the flow of CO_2 when predetermined temperatures are reached. Excessive sizing of orifices causes temperature overrides and snow.

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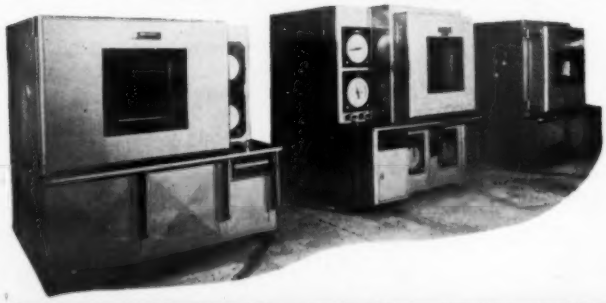

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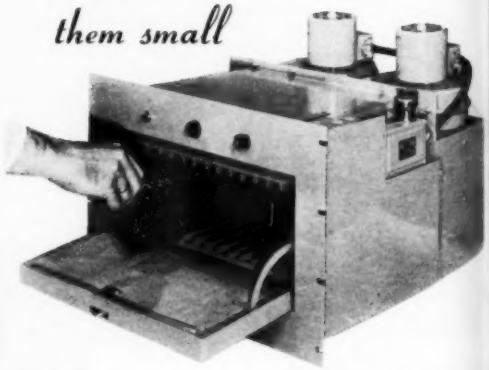

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ENVIRONMENTAL BUSINESS...

CEC's Rochester Division Incorporates; Joins Tenney in Joint Venture Agreement

With an eye to the "technical requirements of the space age," Consolidated Electrodynamics Corporation has turned its Rochester division, producer of high-vacuum and other environmental test equipment into a wholly owned subsidiary, Consolidated Vacuum Corp. One purpose was "to accelerate a planned and aggressive program for the acquisition of new products and product lines."

A recent move in that direction was the signing of a joint venture agreement with Tenney Engineering, Inc., Union, N. J., manufacturer of environmental chambers. The two firms will pool engineering skills and production facilities in R & D, design and construction of extreme high altitude equipment "to meet pressing needs for advanced test equipment to measure the performance and reaction of men and machines in space."

Frank M. Jenner

The announcement said they "will work together in bidding on environmental chambers, with Tenney in most instances the prime contractor and Consolidated as a joint participant."

Philip S. Fogg, chairman and president of CEC, is also chairman of CVC, and Frank M. Jenner, who was general manager of the Rochester division, becomes the new subsidiary's president.

• Merger Move Deferred

Meanwhile, a planned merger of Tenney and Victoreen Instrument Co., a Cleveland based company in the electronics and nuclear and radiation instrumentation field, was deferred. Directors of both companies said increased volume of business and work involved in other expansion activity made the step inadvisable "at this time."

A recent expansion move by Tenney has been the acquisition by its refrigeration components division of the copper and aluminum coil department business of The Kirsch Company, Sturgis, Mich.

Foreign Alliances

Barry Controls, Inc., Watertown, Mass., and Tenney Engineering, Inc., Union, N. J., have announced licensing arrangements with firms overseas. Barry has licensed Showa Electric Wire and Cable Co., of Japan, to make and sell its line of machinery leveling mounts exclusively in Japan and non-exclusively in Latin America. Tenney's arrangement is with DWM (Deutsche Waggon und Maschinenfabriken), which will utilize Tenney's design and engineering techniques to manufacture environmental test equipment in the European market.

Companies At Work

Avco Corporation has received two nose cone orders totaling well over 100-million dollars. The larger, a $73-million contract for the Titan ICBM, is for an advanced design in which re-entry heat will be carried off by "cooking away" heat resistant materials, rather than being absorbed in a heavy metal cap. The other is a $36-million R & D contract for the Minuteman, first solid-fuel ICBM.

International Radiant Corp., of the Bronx, N. Y., has received a contract for a series of environmental test chambers for the Army Ordnance lab at Picatinny Arsenal, Dover, N. J. They will be temp-alt-hum jobs up to 200,000 feet, plus 400°F and full humidity range; and temp-hum from —100° to plus 250° also with full humidity.

MB Electronics has a $300,000 contract from Aerojet-General for a complex motion testing system that can duplicate in-flight vibrations on completed rocket engines systems. These vibrations indirectly or directly are said to cause 40 per cent of all failures.

General Electric has a sub-contract for an undisclosed amount for early R & D for the re-entry sub-system for the newest air-launched ballistic missile, the XGAM-87A. Douglas is the prime contractor. Earlier this summer GE got a $5½-million prime contract to develop the satellite space vehicle for the Notus program.

Blue M Electric Co. is adding 21,600 square feet to its Blue Island, Ill., departments and loading and unloading facilities. Move-in date is early December.

Swinging Its Weight

Model RCT-21 is one of the bigger centrifuge acceleration testers being turned out by The Rucker Company, Oakland, Calif., manufacturer of hydraulic power systems and missile ground support equipment. Recent Rucker installations include Martin-Denver, Lockheed-Sunnyvale, Redstone, Douglas-Santa Monica and GE-Pittsfield. A contract for the hydraulic system to control 400-ton concrete doors protecting Forbes AFB's Atlases was awarded Rucker recently.

One for the Road – Environmental Style

Mobile exhibit developed by Pure Carbonic Company to demonstrate the use of liquid state carbon dioxide in environmental testing is touring the West, with 65 missile and aircraft component manufacturers on its itinerary. Typical of storage units made available by Pureco are a stationary six-tonner and a mobile half-ton unit for which are claimed storage without loss over an indefinite period. A portable servo temperature conditioning unit by Wyle Mfg. Co. which is cooperating in the exhibit, is said to provide —100° to +400°F, within plus or minus 2°. Rapid pull-downs and combined testing are also demonstrated on the 40-foot trailer, which is due to visit other parts of the country later on.

Cincinnati Sub-Zero Radiation Chamber

Cincinnati Sub-Zero Products, Cincinnati, Ohio, has developed an unusual chamber that combines fairly extreme temperatures, altitude and humidity with radiation. The first of the line, a three-cubic-foot unit, was delivered to Bendix Aviation in Cincinnati for electronics testing.

Constructed of ¼-inch plate steel, with a 18x18x12-inch deep test area, the Bendix chamber has an adjustable temperature range from —80° to +180°F., altitude from sea level to 100,000 feet in 15 minutes and up to 100% relative humidity. Because a water supply unit is mounted directly on the unit, it is completely mobile on four six-inch casters.

When radiation is desired, a capsule of radioactive material is inserted into a one-inch metallic tube that penetrates through the chamber and extends six inches on each side.

Other special accessories include pro-

gram controllers for wet and dry bulb temperatures and absolute pressure. The chamber has interior illumination and an 8 x 8-inch observation window.

Offers 'Package' Service

United States Testing Company has a new package service to verify that test equipment calibration meets government standards. Included are a certificate guaranteeing that comparison has been made and a data sheet log of calibration at various points of the equipment scale. The service, on a yearly contract or when-requested basis, will be performed at U. S. Testing's Hoboken, N. J., lab or at the customer's plant.

Transducer Prices Reduced

Ultradyne, Incorporated, has reduced prices an average of 18 per cent on variable reluctance pressure transducers. The company has a new line of pressure measuring systems in which variable reluctance transducers are packaged with electronic circuitry to furnish either FM or high-level DC output signals.

Sales Reps Appointed

Ling Electronics, Inc., has named *Tek-Sel, Inc.*, of Paramus, N. J., as sales rep in metropolitan New York City, New Jersey, Delaware and eastern Pennsylvania for Ling's line of electronically-driven vibration testing systems and high-power electronic equipment.

L.A.B. Corp., of Skaneateles, N. Y., has appointed *Don E. Hughes Co.*, Glendale, Calif., as its representative in California and Arizona for environmental shock and vibration machines and transportation testing equipment.

Ultradyne, Incorporated, has appointed a number of manufacturer's representatives in the East for its pressure transducers, pressure measuring systems and reactance controlled oscillators. They are: New England—*Adellco Co.*, of West Roxbury, Mass.; eastern Pennsylvania and southern New Jersey—*Holdsworth Co.*, Landsdowne, Pa.; metropolitan New York—*Memo, Inc.*, Hempstead, N. Y.; northern New York—*Charles A. Winick Co.*, Schenectady.

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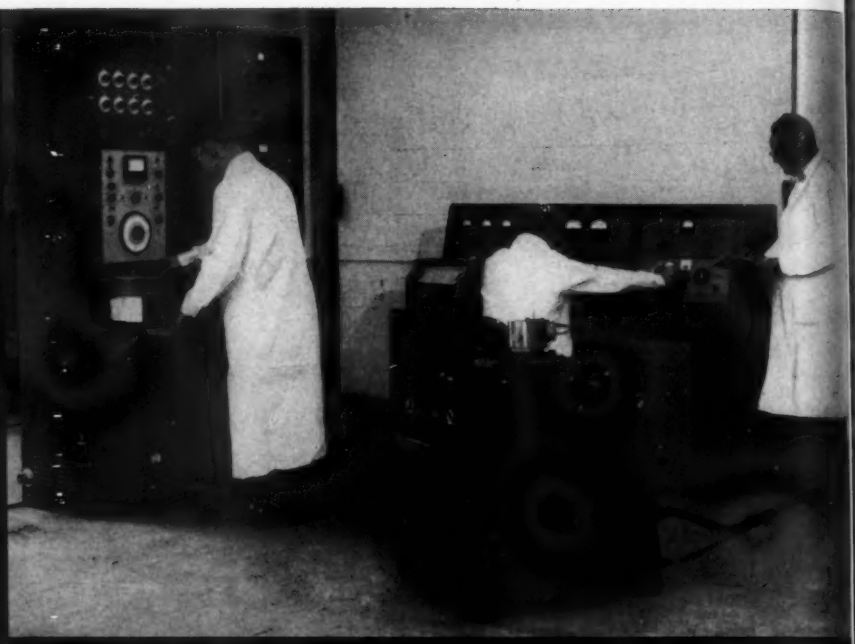

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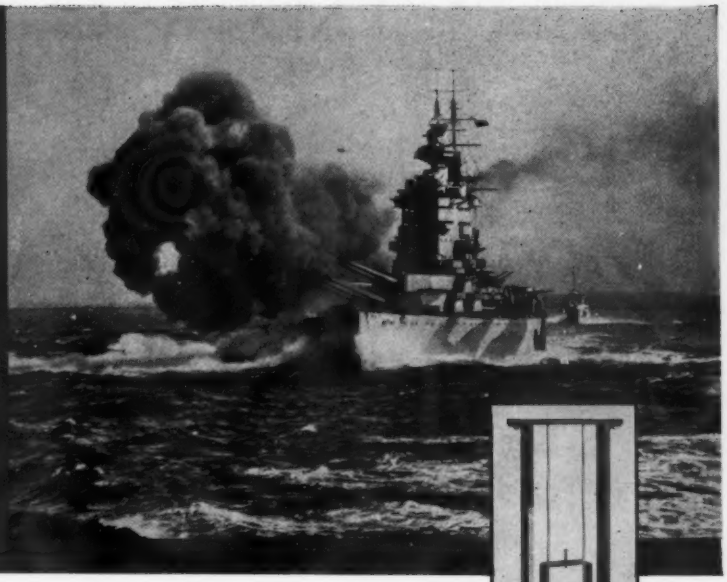

SHOCK TESTING

(FIRST OF A SERIES)

JAN-S-44
Machine

While many people had been interested in the effects of shock for years, it was not until World War II that the phenomenon began to be studied on a scientific basis. Proper credit for beginning the study belongs to the British Admiralty.

The shock problem came into focus when the ship's guns were fired or when a ship experienced a "near miss". The hull remained undamaged, but equipment was often rendered inoperative by the shock, even to the extent of crippling the ship. In addition, the cast-iron mounting feet used on much of the equipment would often fracture under shock, allowing the equipment to "float" within the hull and constituting a personnel hazard.

Under wartime pressures to preserve every ship for service, the English designed the classic "high impact" machine to study the problem. This device simulated a bulkhead with heavy steel plate and dropped a 400-pound weight against it. The maximum drop height was five feet, with the intent of duplicating the effect of guns and near misses. Basically, this first shock testing machine was designed to *simulate damage* rather than to *define shock pulses.*

The machine was modified and manufactured for the U. S. Navy and has been used in the standard Navy tests for qualifying shipboard equipment up to present times. The original machine, called the light-weight high-impact shock machine, used a 400-pound hammer and tested equipments up to 400 pounds. A medium-weight high-impact machine followed, which used a 3000-pound hammer and tested equipments up to 4500 pounds. A high-impact machine for equipment weights over 4500 pounds has been designed but has never been manufactured.

Little work has been done on studying the shock motion produced by these machines. One good reference is "A Guide for Design of Shock Resistant Naval Equipment," published in 1949 as an unclassified, non-registered publication by the Bureau of Ships and written by Charles E. Crede and Miguel C. Junger of Barry Controls.

While the high-impact machine solved the immediate wartime problems of shock testing for shipboard installations, and is still in use in most well-equipped laboratories, it was inadequate for studying the variety of shock problems associated with small electronic equipment. The sudden, high shock of big guns and near misses was not the sort of shock experienced by smaller components in terms of peak acceleration and time duration. To solve this problem, the Armed Forces developed JAN-S-44 specification, defining a machine to test for such shocks as encountered in handling and shipping. Built to specification by a number of suppliers, among them JAN Hardware Manufacturing Company in Long Island City and the New England Trawler Equipment Company of Chelsea, Massachusetts, the JAN-S-44 machine utilized the free-fall gravity drop principle. It dropped a spring-mounted platform against a tool-steel plate, with manual lift and rebound catch.

The JAN-S-44 machine had a nominal load capacity of only four pounds, and the growing weight and complexity of avionic gear forced a modification of the basic approach. While use of the gravity free-fall technique had proved feasible, the problems inherent in larger loads, controlled rebound and different wave shapes, together with those involved in spring constants, made it clearly apparent that a different design would have to be used to meet the changed requirements.

(To be continued)

Write for: "Designing for Shock Resistance" by Charles E. Crede and Miguel C. Junger.

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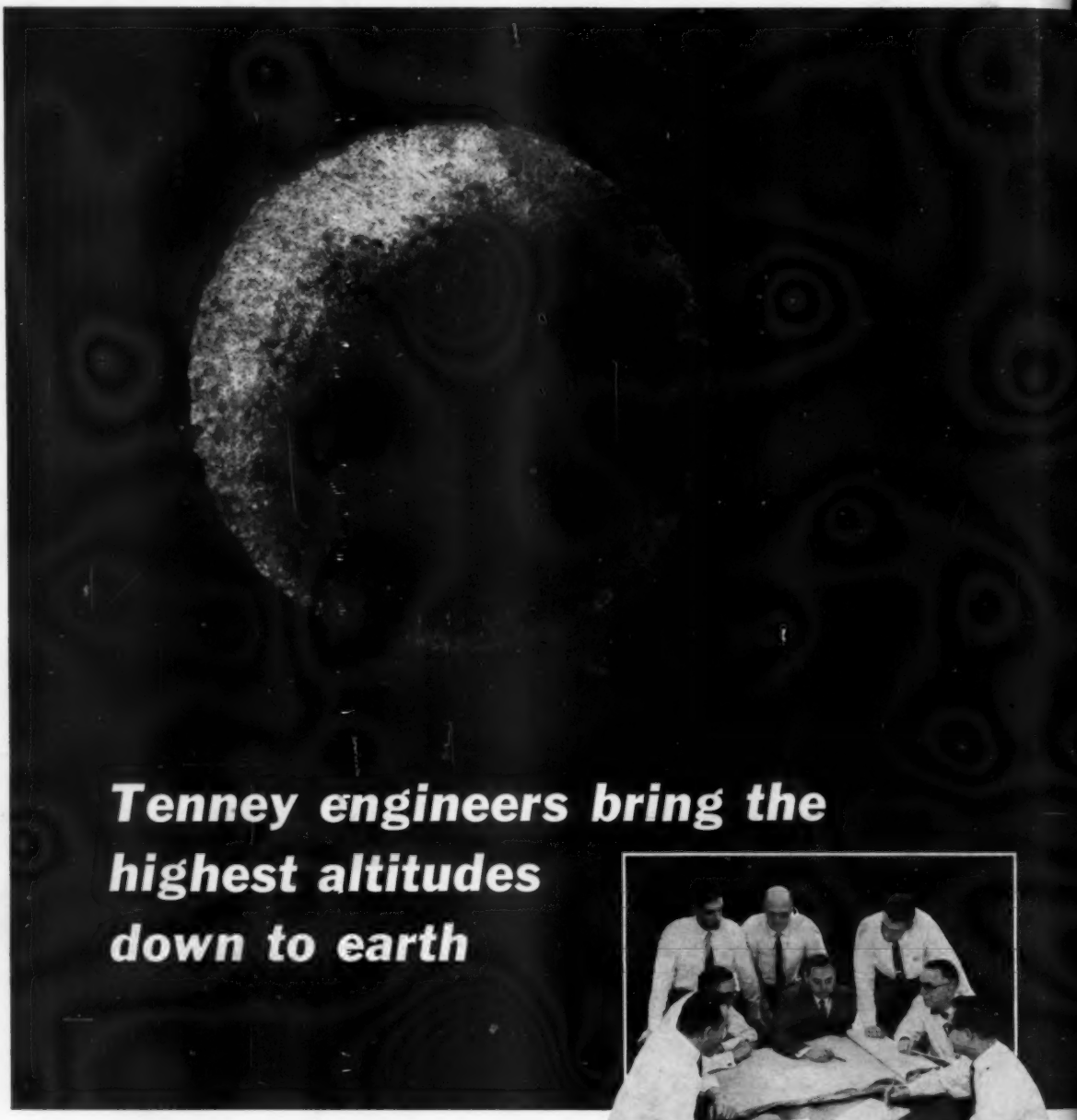

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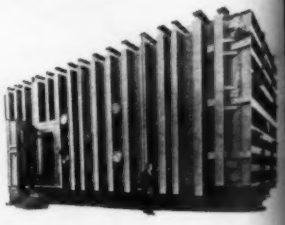

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